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**Dental wear patterns of hunter-gatherers and agriculturalists: The impact of behavioural changes accompanying the transition**

Thesis Submitted to the University of London for the  
Degree of Doctor of Philosophy

By

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December 2004

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## **Abstract**

Tooth wear can record valuable information on diet, and non-dietary activities in different populations. In this study, assemblages from various behavioural groups are used to test the hypothesis that non-agriculturalists had a characteristic pattern of tooth wear which differs from the pattern of tooth wear of agriculturalists. The current study used an updated method to measure the proportions of dentine exposed in the occlusal wear facet and compared this to approximal wear and occlusal wear plane angle (separately). Assemblages used were from different behavioural groups (non-agriculturalists, transitionals and agriculturalists), environments (inland and coastal) and regions (North America and Levant). The non-agricultural groups were made up of assemblages from Carlston Annis, Ciggerville, El Wad, Indian Knoll and Kebara. The transitional group was from Calhoun County and the agriculturalists were made up of assemblages from Abu Hureyra, Florida Canaveral Peninsula, Hawikuh and Shannon. Results showed that the rate of occlusal wear corresponds greatly with the eruption timing of the dentition, agriculturalists and transitionals had greater approximal wear relative to M1 occlusal wear than non-agriculturalists and non-agriculturalists had a slower rate of change in occlusal facet angle relative to the extent of occlusal wear than the agriculturalists and transitionals.



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- 7.76 Scatter plot of the dentine percent of I2 plotted against M1 from the different sex groups
- 7.77 Scatter plot of the dentine percent of C plotted against M1 from the different sex groups
- 7.78 Scatter plot of the dentine percent of P1 plotted against M1 from the different sex groups
- 7.79 Scatter plot of the dentine percent of P2 plotted against M1 from the different sex groups
- 7.80 Scatter plot of the dentine percent of M2 plotted against M1 from the different sex groups
- 7.81 Scatter plot of the dentine percent of M3 plotted against M1 from the different sex groups
- 7.82 Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for the different sex groups anterior teeth
- 7.83 Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for the different sex groups premolars
- 7.84 Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for the different sex groups molars
- 7.85 Scatter plot of the approximal facet length (mm) of lower right I1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.86 Scatter plot of the approximal facet length (mm) of lower left I1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.87 Scatter plot of the approximal facet length (mm) of lower right I2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.88 Scatter plot of the approximal facet length (mm) of lower left I2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.89 Scatter plot of the approximal facet length (mm) of lower right C plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.90 Scatter plot of the approximal facet length (mm) of lower left C plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.91 Scatter plot of the approximal facet length (mm) of lower right P1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.92 Scatter plot of the approximal facet length (mm) of lower left P1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.93 Scatter plot of the approximal facet length (mm) of lower right P2 plotted against occlusal wear (dentine percent for M1) for the different sex groups

- 7.94 Scatter plot of the approximal facet length (mm) of lower left P2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.95 Scatter plot of the approximal facet length (mm) of lower right M1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.96 Scatter plot of the approximal facet length (mm) of lower left M1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.97 Scatter plot of the approximal facet length (mm) of lower right M2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.98 Scatter plot of the approximal facet length (mm) of lower left M2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.99 Scatter plot of the approximal facet length (mm) of lower right M3 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.100 Scatter plot of the approximal facet length (mm) of lower left M3 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.101 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the sex groups right anterior teeth
- 7.102 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the sex groups left anterior teeth
- 7.103 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the sex groups right premolars
- 7.104 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the sex groups left premolars
- 7.105 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the sex groups right molars
- 7.106 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the sex groups left molars
- 7.107 Scatter plot of the M1 occlusal angle plotted against M1 occlusal wear (dentine percent), for different sex groups
- 7.108 Scatter plot of the M2 occlusal angle plotted against M1 occlusal wear (dentine percent), for different sex groups
- 7.109 Box plots of the occlusal wear plane angle (OA), expressed as proportion of the first molar dentine percent (DPM1), for the sex groups
- 7.2.B. Comparison of the coastal agriculturalists and coastal non-agriculturalists**
- 7.110 Scatter plot of the dentine percent of I1 plotted against M1 for the coastal groups
- 7.111 Scatter plot of the dentine percent of I2 plotted against M1 for the coastal groups
- 7.112 Scatter plot of the dentine percent of C plotted against M1 for the coastal groups
- 7.113 Scatter plot of the dentine percent of P1 plotted against M1 for the coastal groups
- 7.114 Scatter plot of the dentine percent of P2 plotted against M1 for the coastal groups
- 7.115 Scatter plot of the dentine percent of M2 plotted against M1 for the coastal groups
- 7.116 Scatter plot of the dentine percent of M3 plotted against M1 for the coastal groups
- 7.117 Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the coastal collections anterior teeth
- 7.118 Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the coastal collections premolars
- 7.119 Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the coastal collections molars
- 7.120 Scatter plot of the approximal facet length (mm) of lower right I1 plotted against occlusal wear (dentine percent for M1) for the different coastal groups
- 7.121 Scatter plot of the approximal facet length (mm) of lower left I1 plotted against occlusal wear (dentine percent for M1) for the different coastal groups
- 7.122 Scatter plot of the approximal facet length (mm) of lower right I2 plotted against occlusal wear (dentine percent for M1) for the different coastal groups

- 7.123 Scatter plot of the approximal facet length (mm) of lower left I2 plotted against occlusal wear (dentine percent for M1) for the different coastal groups
- 7.124 Scatter plot of the approximal facet length (mm) of lower right C plotted against occlusal wear (dentine percent for M1) for the different coastal groups
- 7.125 Scatter plot of the approximal facet length (mm) of lower left C plotted against occlusal wear (dentine percent for M1) for the different coastal groups
- 7.126 Scatter plot of the approximal facet length (mm) of lower right P1 plotted against occlusal wear (dentine percent for M1) for the different coastal groups
- 7.127 Scatter plot of the approximal facet length (mm) of lower left P1 plotted against occlusal wear (dentine percent for M1) for the different coastal groups
- 7.128 Scatter plot of the approximal facet length (mm) of lower right P2 plotted against occlusal wear (dentine percent for M1) for the different coastal groups
- 7.129 Scatter plot of the approximal facet length (mm) of lower left P2 plotted against occlusal wear (dentine percent for M1) for the different coastal groups
- 7.130 Scatter plot of the approximal facet length (mm) of lower right M1 plotted against occlusal wear (dentine percent for M1) for the different coastal groups
- 7.131 Scatter plot of the approximal facet length (mm) of lower left M1 plotted against occlusal wear (dentine percent for M1) for the different coastal groups
- 7.132 Scatter plot of the approximal facet length (mm) of lower right M2 plotted against occlusal wear (dentine percent for M1) for the different coastal groups
- 7.133 Scatter plot of the approximal facet length (mm) of lower left M2 plotted against occlusal wear (dentine percent for M1) for the different coastal groups
- 7.134 Scatter plot of the approximal facet length (mm) of lower right M3 plotted against occlusal wear (dentine percent for M1) for the different coastal groups
- 7.135 Scatter plot of the approximal facet length (mm) of lower left M3 plotted against occlusal wear (dentine percent for M1) for the different coastal groups
- 7.136 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the coastal collections right anterior teeth
- 7.137 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the coastal collections left anterior teeth
- 7.138 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the coastal collections right premolars
- 7.139 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the coastal collections left premolars
- 7.140 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the coastal collections right molars
- 7.141 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the coastal collections left molars
- 7.142 Scatter plot of the M1 occlusal angle plotted against M1 occlusal wear (dentine percent), for different coastal groups
- 7.143 Scatter plot of the M1 occlusal angle plotted against M2 occlusal wear (dentine percent), for different coastal groups
- 7.144 Box plots of the occlusal wear plane angle (OA), expressed as a proportion of the first molar dentine percent (DPM1), for the coastal collections

#### **Sex comparisons**

- 7.145 Scatter plot of the dentine percent of I1 plotted against M1 from the different sex groups
- 7.146 Scatter plot of the dentine percent of I2 plotted against M1 from the different sex groups
- 7.147 Scatter plot of the dentine percent of C plotted against M1 from the different sex groups
- 7.148 Scatter plot of the dentine percent of P1 plotted against M1 from the different sex groups

- 7.149 Scatter plot of the dentine percent of P2 plotted against M1 from the different sex groups
- 7.150 Scatter plot of the dentine percent of M2 plotted against M1 from the different sex groups
- 7.151 Scatter plot of the dentine percent of M3 plotted against M1 from the different sex groups
- 7.152 Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the different sex groups anterior teeth
- 7.153 Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the different sex groups premolars
- 7.154 Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the different sex groups molars
- 7.155 Scatter plot of the approximal facet length (mm) of lower right I1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.156 Scatter plot of the approximal facet length (mm) of lower left I1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.157 Scatter plot of the approximal facet length (mm) of lower right I2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.158 Scatter plot of the approximal facet length (mm) of lower left I2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.159 Scatter plot of the approximal facet length (mm) of lower right C plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.160 Scatter plot of the approximal facet length (mm) of lower left C plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.161 Scatter plot of the approximal facet length (mm) of lower right P1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.162 Scatter plot of the approximal facet length (mm) of lower left P1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.163 Scatter plot of the approximal facet length (mm) of lower right P2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.164 Scatter plot of the approximal facet length (mm) of lower left P2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.165 Scatter plot of the approximal facet length (mm) of lower right M1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.166 Scatter plot of the approximal facet length (mm) of lower left M1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.167 Scatter plot of the approximal facet length (mm) of lower right M2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.168 Scatter plot of the approximal facet length (mm) of lower left M2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.169 Scatter plot of the approximal facet length (mm) of lower right M3 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.170 Scatter plot of the approximal facet length (mm) of lower left M3 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.171 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups right anterior teeth
- 7.172 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups left anterior teeth
- 7.173 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups right premolars
- 7.174 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups left premolars

- 7.175 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups right molars
- 7.176 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups left molars
- 7.177 Scatter plot of M1 occlusal angle plotted against M1 occlusal wear (dentine percent), for different sex groups
- 7.178 Scatter plot of M2 occlusal angle plotted against M1 occlusal wear (dentine percent), for different sex groups
- 7.179 Box plots of the occlusal wear plane angle (OA), expressed as a proportion of the first molar dentine percent (DPM1), for the sex groups
- 7.2.C. Comparison of the inland agriculturalists to inland transitional to inland non-agriculturalists**
- 7.180 Scatter plot of the dentine percent on I1 plotted against M1 for the inland groups
- 7.181 Scatter plot of the dentine percent on I2 plotted against M1 for the inland groups
- 7.182 Scatter plot of the dentine percent on C plotted against M1 for the inland groups
- 7.183 Scatter plot of the dentine percent on P1 plotted against M1 for the inland groups
- 7.184 Scatter plot of the dentine percent on P2 plotted against M1 for the inland groups
- 7.185 Scatter plot of the dentine percent on M2 plotted against M1 for the inland groups
- 7.186 Scatter plot of the dentine percent on M3 plotted against M1 for the inland groups
- 7.187 Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for inland behavioural groups anterior teeth
- 7.188 Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for inland behavioural groups premolars
- 7.189 Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for inland behavioural groups molars
- 7.190 Scatter plot of the approximal facet length (mm) of lower right I1 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups
- 7.191 Scatter plot of the approximal facet length (mm) of lower left I1 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups
- 7.192 Scatter plot of the approximal facet length (mm) of lower right I2 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups
- 7.193 Scatter plot of the approximal facet length (mm) of lower left I2 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups
- 7.194 Scatter plot of the approximal facet length (mm) of lower right C plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups
- 7.195 Scatter plot of the approximal facet length (mm) of lower left C plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups
- 7.196 Scatter plot of the approximal facet length (mm) of lower right P1 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups
- 7.197 Scatter plot of the approximal facet length (mm) of lower left P1 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups
- 7.198 Scatter plot of the approximal facet length (mm) of lower right P2 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups
- 7.199 Scatter plot of the approximal facet length (mm) of lower left P2 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups
- 7.200 Scatter plot of the approximal facet length (mm) of lower right M1 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups
- 7.201 Scatter plot of the approximal facet length (mm) of lower left M1 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups
- 7.202 Scatter plot of the approximal facet length (mm) of lower right M2 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups
- 7.203 Scatter plot of the approximal facet length (mm) of lower left M2 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups

- 7.204 Scatter plot of the approximal facet length (mm) of lower right M3 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups
- 7.205 Scatter plot of the approximal facet length (mm) of lower left M3 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups
- 7.206 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the inland behavioural groups right anterior teeth
- 7.207 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the inland behavioural groups left anterior teeth
- 7.208 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the inland behavioural groups right premolars
- 7.209 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the inland behavioural groups left premolars
- 7.210 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the inland behavioural groups right molars
- 7.211 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the inland behavioural groups left molars
- 7.212 Scatter plot of the M1 occlusal angle plotted against M1 occlusal wear (dentine percent), for different inland behavioural groups
- 7.213 Scatter plot of the M2 occlusal angle plotted against M1 occlusal wear (dentine percent), for different inland behavioural groups
- 7.214 Box plot of the occlusal angle measurement from the first and second molars (M1 and M2) ratios (over first molar (M1) dentine percent DP) for the inland groups

#### **Sex comparisons**

- 7.215 Scatter plot of the dentine percent of I1 plotted against M1 from the different sex groups
- 7.216 Scatter plot of the dentine percent of I2 plotted against M1 from the different sex groups
- 7.217 Scatter plot of the dentine percent of C plotted against M1 from the different sex groups
- 7.218 Scatter plot of the dentine percent of P1 plotted against M1 from the different sex groups
- 7.219 Scatter plot of the dentine percent of P2 plotted against M1 from the different sex groups
- 7.220 Scatter plot of the dentine percent of M2 plotted against M1 from the different sex groups
- 7.221 Scatter plot of the dentine percent of M3 plotted against M1 from the different sex groups
- 7.222 Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the different sex groups anterior teeth
- 7.223 Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the different sex groups premolars
- 7.224 Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the different sex groups molars
- 7.225 Scatter plot of the approximal facet length (mm) of lower right I1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.226 Scatter plot of the approximal facet length (mm) of lower left I1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.227 Scatter plot of the approximal facet length (mm) of lower right I2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.228 Scatter plot of the approximal facet length (mm) of lower left I2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.229 Scatter plot of the approximal facet length (mm) of lower right C plotted against occlusal wear (dentine percent for M1) for the different sex groups

- 7.230 Scatter plot of the approximal facet length (mm) of lower left C plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.231 Scatter plot of the approximal facet length (mm) of lower right P1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.232 Scatter plot of the approximal facet length (mm) of lower left P1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.233 Scatter plot of the approximal facet length (mm) of lower right P2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.234 Scatter plot of the approximal facet length (mm) of lower left P2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.235 Scatter plot of the approximal facet length (mm) of lower right M1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.236 Scatter plot of the approximal facet length (mm) of lower left M1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.237 Scatter plot of the approximal facet length (mm) of lower right M2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.238 Scatter plot of the approximal facet length (mm) of lower left M2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.239 Scatter plot of the approximal facet length (mm) of lower right M3 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.240 Scatter plot of the approximal facet length (mm) of lower left M3 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.241 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups right anterior teeth
- 7.242 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups left anterior teeth
- 7.243 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups right premolars
- 7.244 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups left premolars
- 7.245 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups right molars
- 7.246 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups left molars
- 7.247 Scatter plot of M1 occlusal angle plotted against M1 occlusal wear (dentine percent), for different sex groups
- 7.248 Scatter plot of M2 occlusal angle plotted against M1 occlusal wear (dentine percent), for different sex groups
- 7.249 Box plots of the occlusal wear plane angle (OA), expressed as a proportion of the first molar dentine percent (DPM1), for the sex groups
- 7.3. Non-agriculturalists comparisons**
- 7.3.A All non-agricultural groups**
- 7.250 Scatter plot of the dentine percent of I1 plotted against M1 from the non-agriculturalists
- 7.251 Scatter plot of the dentine percent of I2 plotted against M1 from the non-agriculturalists
- 7.252 Scatter plot of the dentine percent of C plotted against M1 from the non-agriculturalists
- 7.253 Scatter plot of the dentine percent of P1 plotted against M1 from the non-agriculturalists
- 7.254 Scatter plot of the dentine percent of P2 plotted against M1 from the non-agriculturalists

- 7.255 Scatter plot of the dentine percent of M2 plotted against M1 from the non-agriculturalists
- 7.256 Scatter plot of the dentine percent of M3 plotted against M1 from the non-agriculturalists
- 7.257 Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for the non-agriculturalists anterior teeth
- 7.258 Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for the non-agriculturalists premolars
- 7.259 Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for the non-agriculturalists molars
- 7.260 Scatter plot of the approximal facet length (mm) of lower right I1 plotted against occlusal wear (dentine percent for M1) for the different non-agriculturalists
- 7.261 Scatter plot of the approximal facet length (mm) of lower left I1 plotted against occlusal wear (dentine percent for M1) for the different non-agriculturalists
- 7.262 Scatter plot of the approximal facet length (mm) of lower right I2 plotted against occlusal wear (dentine percent for M1) for the different non-agriculturalists
- 7.263 Scatter plot of the approximal facet length (mm) of lower left I2 plotted against occlusal wear (dentine percent for M1) for the different non-agriculturalists
- 7.264 Scatter plot of the approximal facet length (mm) of lower right C plotted against occlusal wear (dentine percent for M1) for the different non-agriculturalists
- 7.265 Scatter plot of the approximal facet length (mm) of lower left C plotted against occlusal wear (dentine percent for M1) for the different non-agriculturalists
- 7.266 Scatter plot of the approximal facet length (mm) of lower right P1 plotted against occlusal wear (dentine percent for M1) for the different non-agriculturalists
- 7.267 Scatter plot of the approximal facet length (mm) of lower left P1 plotted against occlusal wear (dentine percent for M1) for the different non-agriculturalists
- 7.268 Scatter plot of the approximal facet length (mm) of lower right P2 plotted against occlusal wear (dentine percent for M1) for the different non-agriculturalists
- 7.269 Scatter plot of the approximal facet length (mm) of lower right P2 plotted against occlusal wear (dentine percent for M1) for the different non-agriculturalists
- 7.270 Scatter plot of the approximal facet length (mm) of lower right M1 plotted against occlusal wear (dentine percent for M1) for the different non-agriculturalists
- 7.271 Scatter plot of the approximal facet length (mm) of lower left M1 plotted against occlusal wear (dentine percent for M1) for the different non-agriculturalists
- 7.272 Scatter plot of the approximal facet length (mm) of lower right M2 plotted against occlusal wear (dentine percent for M1) for the different non-agriculturalists
- 7.273 Scatter plot of the approximal facet length (mm) of lower left M2 plotted against occlusal wear (dentine percent for M1) for the different non-agriculturalists
- 7.274 Scatter plot of the approximal facet length (mm) of lower right M3 plotted against occlusal wear (dentine percent for M1) for the different non-agriculturalists
- 7.275 Scatter plot of the approximal facet length (mm) of lower left M3 plotted against occlusal wear (dentine percent for M1) for the different non-agriculturalists
- 7.276 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the non-agriculturalists right anterior teeth
- 7.277 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the non-agriculturalists left anterior teeth
- 7.278 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the non-agriculturalists right premolars
- 7.279 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the non-agriculturalists left premolars
- 7.280 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the non-agriculturalists right molars



- 7.281 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the non-agriculturalists left molars
- 7.282 Scatter plot of M1 occlusal angle plotted against M1 occlusal wear (dentine percent), for different non-agriculturalists
- 7.283 Scatter plot of M2 occlusal angle plotted against M1 occlusal wear (dentine percent), for different non-agriculturalists
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- 7.346 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the North American and Levant groups right anterior teeth
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- 7.348 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the North American and Levant groups right premolars
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- 7.359 Scatter plot of the dentine percent of P2 plotted against M1 for the coastal and inland non-agriculturalists
- 7.360 Scatter plot of the dentine percent of M2 plotted against M1 for the coastal and inland non-agriculturalists
- 7.361 Scatter plot of the dentine percent of M3 plotted against M1 for the coastal and inland non-agriculturalists
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- 7.365 Scatter plot of the approximal facet length (mm) of lower right I1 plotted against occlusal wear (dentine percent for M1) for the coastal and inland non-agriculturalists
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- 7.368 Scatter plot of the approximal facet length (mm) of lower left I2 plotted against occlusal wear (dentine percent for M1) for the coastal and inland non-agriculturalists
- 7.369 Scatter plot of the approximal facet length (mm) of lower right C plotted against occlusal wear (dentine percent for M1) for the coastal and inland non-agriculturalists
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- 7.371 Scatter plot of the approximal facet length (mm) of lower right P1 plotted against occlusal wear (dentine percent for M1) for the coastal and inland non-agriculturalists
- 7.372 Scatter plot of the approximal facet length (mm) of lower left P1 plotted against occlusal wear (dentine percent for M1) for the coastal and inland non-agriculturalists
- 7.373 Scatter plot of the approximal facet length (mm) of lower right P2 plotted against occlusal wear (dentine percent for M1) for the coastal and inland non-agriculturalists
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- 7.376 Scatter plot of the approximal facet length (mm) of lower left M1 plotted against occlusal wear (dentine percent for M1) for the coastal and inland non-agriculturalists
- 7.377 Scatter plot of the approximal facet length (mm) of lower right M2 plotted against occlusal wear (dentine percent for M1) for the coastal and inland non-agriculturalists
- 7.378 Scatter plot of the approximal facet length (mm) of lower left M2 plotted against occlusal wear (dentine percent for M1) for the coastal and inland non-agriculturalists
- 7.379 Scatter plot of the approximal facet length (mm) of lower right M3 plotted against occlusal wear (dentine percent for M1) for the coastal and inland non-agriculturalists

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- 7.383 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the coastal and inland non-agricultural collections right premolars
- 7.384 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the coastal and inland non-agricultural collections left premolars
- 7.385 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the coastal and inland non-agricultural collections right molars
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- 7.387 Scatter plot of the M1 occlusal angle plotted against M1 occlusal wear (dentine percent), for coastal and inland non-agriculturalists
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- 7.389 Box plots of the occlusal wear plane angle (OA), expressed as a proportion of the first molar dentine percent (DPM1), for the coastal and inland non-agricultural collections

#### **7.4. Agriculturalists comparisons**

##### **7.4.A All agricultural groups**

- 7.390 Scatter plot of the dentine percent of I1 plotted against M1 from the agriculturalists
- 7.391 Scatter plot of the dentine percent of I2 plotted against M1 from the agriculturalists
- 7.392 Scatter plot of the dentine percent of C plotted against M1 from the agriculturalists
- 7.393 Scatter plot of the dentine percent of P1 plotted against M1 from the agriculturalists
- 7.394 Scatter plot of the dentine percent of P2 plotted against M1 from the agriculturalists
- 7.395 Scatter plot of the dentine percent of M2 plotted against M1 from the agriculturalists
- 7.396 Scatter plot of the dentine percent of M3 plotted against M1 from the agriculturalists
- 7.397 Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for the agriculturalists anterior teeth
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- 7.400 Scatter plot of the approximal facet length (mm) of lower right I1 plotted against occlusal wear (dentine percent for M1) for the different agriculturalists
- 7.401 Scatter plot of the approximal facet length (mm) of lower left I1 plotted against occlusal wear (dentine percent for M1) for the different agriculturalists
- 7.402 Scatter plot of the approximal facet length (mm) of lower right I2 plotted against occlusal wear (dentine percent for M1) for the different agriculturalists

- 7.403 Scatter plot of the approximal facet length (mm) of lower left I2 plotted against occlusal wear (dentine percent for M1) for the different agriculturalists
- 7.404 Scatter plot of the approximal facet length (mm) of lower right C plotted against occlusal wear (dentine percent for M1) for the different agriculturalists
- 7.405 Scatter plot of the approximal facet length (mm) of lower left C plotted against occlusal wear (dentine percent for M1) for the different agriculturalists
- 7.406 Scatter plot of the approximal facet length (mm) of lower right P1 plotted against occlusal wear (dentine percent for M1) for the different agriculturalists
- 7.407 Scatter plot of the approximal facet length (mm) of lower left P1 plotted against occlusal wear (dentine percent for M1) for the different agriculturalists
- 7.408 Scatter plot of the approximal facet length (mm) of lower right P2 plotted against occlusal wear (dentine percent for M1) for the different agriculturalists
- 7.409 Scatter plot of the approximal facet length (mm) of lower right P2 plotted against occlusal wear (dentine percent for M1) for the different agriculturalists
- 7.410 Scatter plot of the approximal facet length (mm) of lower right M1 plotted against occlusal wear (dentine percent for M1) for the different agriculturalists
- 7.411 Scatter plot of the approximal facet length (mm) of lower left M1 plotted against occlusal wear (dentine percent for M1) for the different agriculturalists
- 7.412 Scatter plot of the approximal facet length (mm) of lower right M2 plotted against occlusal wear (dentine percent for M1) for the different agriculturalists
- 7.413 Scatter plot of the approximal facet length (mm) of lower left M2 plotted against occlusal wear (dentine percent for M1) for the different agriculturalists
- 7.414 Scatter plot of the approximal facet length (mm) of lower right M3 plotted against occlusal wear (dentine percent for M1) for the different agriculturalists
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- 7.416 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the agriculturalists right anterior teeth
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- 7.418 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the agriculturalists right premolars
- 7.419 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the agriculturalists left premolars
- 7.420 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the agriculturalists right molars
- 7.421 Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the agriculturalists left molars
- 7.422 Scatter plot of M1 occlusal angle plotted against M1 occlusal wear (dentine percent), for different agriculturalists
- 7.423 Scatter plot of M2 occlusal angle plotted against M1 occlusal wear (dentine percent), for different agriculturalists
- 7.424 Box plots of the occlusal wear plane angle (OA), expressed as proportion of the first molar dentine percent (DPM1), for the agriculturalists

#### **Sex comparisons**

- 7.425 Scatter plot of the dentine percent of I1 plotted against M1 from the different sex groups
- 7.426 Scatter plot of the dentine percent of I2 plotted against M1 from the different sex groups
- 7.427 Scatter plot of the dentine percent of C plotted against M1 from the different sex groups
- 7.428 Scatter plot of the dentine percent of P1 plotted against M1 from the different sex groups

- 7.429 Scatter plot of the dentine percent of P2 plotted against M1 from the different sex groups
- 7.430 Scatter plot of the dentine percent of M2 plotted against M1 from the different sex groups
- 7.431 Scatter plot of the dentine percent of M3 plotted against M1 from the different sex groups
- 7.432 Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the different sex groups anterior teeth
- 7.433 Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the different sex groups premolars
- 7.434 Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the different sex groups molars
- 7.435 Scatter plot of the approximal facet length (mm) of lower right I1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.436 Scatter plot of the approximal facet length (mm) of lower left I1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.437 Scatter plot of the approximal facet length (mm) of lower right I2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.438 Scatter plot of the approximal facet length (mm) of lower left I2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.439 Scatter plot of the approximal facet length (mm) of lower right C plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.440 Scatter plot of the approximal facet length (mm) of lower left C plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.441 Scatter plot of the approximal facet length (mm) of lower right P1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.442 Scatter plot of the approximal facet length (mm) of lower left P1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.443 Scatter plot of the approximal facet length (mm) of lower right P2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.444 Scatter plot of the approximal facet length (mm) of lower left P2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.445 Scatter plot of the approximal facet length (mm) of lower right M1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.446 Scatter plot of the approximal facet length (mm) of lower left M1 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.447 Scatter plot of the approximal facet length (mm) of lower right M2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.448 Scatter plot of the approximal facet length (mm) of lower left M2 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.449 Scatter plot of the approximal facet length (mm) of lower right M3 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.450 Scatter plot of the approximal facet length (mm) of lower left M3 plotted against occlusal wear (dentine percent for M1) for the different sex groups
- 7.451 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups right anterior teeth
- 7.452 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups left anterior teeth
- 7.453 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups right premolars
- 7.454 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups left premolars

- 7.455 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups right molars
- 7.456 Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups left molars
- 7.457 Scatter plot of M1 occlusal angle plotted against M1 occlusal wear (dentine percent), for different sex groups
- 7.458 Scatter plot of M2 occlusal angle plotted against M1 occlusal wear (dentine percent), for different sex groups
- 7.459 Box plots of the occlusal wear plane angle (OA), expressed as a proportion of the first molar dentine percent (DPM1), for the sex groups
- 7.4.B Comparison of the Levant and North American agriculturalists**
- 7.460 Scatter plot of the dentine percent of I1 plotted against M1 for the North American and Levantine groups
- 7.461 Scatter plot of the dentine percent of I2 plotted against M1 for the North American and Levantine groups
- 7.462 Scatter plot of the dentine percent of C plotted against M1 for the North American and Levantine groups
- 7.463 Scatter plot of the dentine percent of P1 plotted against M1 for the North American and Levantine groups
- 7.464 Scatter plot of the dentine percent of P2 plotted against M1 for the North American and Levantine groups
- 7.465 Scatter plot of the dentine percent of M2 plotted against M1 for the North American and Levantine groups
- 7.466 Scatter plot of the dentine percent of M3 plotted against M1 for the North American and Levantine groups
- 7.467 Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the North American and Levantine groups anterior teeth
- 7.468 Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the North American and Levantine groups premolars
- 7.469 Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the North American and Levantine groups molars
- 7.470 Scatter plot of the approximal facet length (mm) of lower right I1 plotted against occlusal wear (dentine percent for M1) for the North American and Levant groups
- 7.471 Scatter plot of the approximal facet length (mm) of lower left I1 plotted against occlusal wear (dentine percent for M1) for the North American and Levant groups
- 7.472 Scatter plot of the approximal facet length (mm) of lower right I2 plotted against occlusal wear (dentine percent for M1) for the North American and Levant groups
- 7.473 Scatter plot of the approximal facet length (mm) of lower left I2 plotted against occlusal wear (dentine percent for M1) for the North American and Levant groups
- 7.474 Scatter plot of the approximal facet length (mm) of lower right C plotted against occlusal wear (dentine percent for M1) for the North American and Levant groups
- 7.475 Scatter plot of the approximal facet length (mm) of lower left C plotted against occlusal wear (dentine percent for M1) for the North American and Levant groups
- 7.476 Scatter plot of the approximal facet length (mm) of lower right P1 plotted against occlusal wear (dentine percent for M1) for the North American and Levant groups
- 7.477 Scatter plot of the approximal facet length (mm) of lower left P1 plotted against occlusal wear (dentine percent for M1) for the North American and Levant groups
- 7.478 Scatter plot of the approximal facet length (mm) of lower right P2 plotted against occlusal wear (dentine percent for M1) for the North American and Levant groups
- 7.479 Scatter plot of the approximal facet length (mm) of lower left P2 plotted against occlusal wear (dentine percent for M1) for the North American and Levant groups
- 7.480 Scatter plot of the approximal facet length (mm) of lower right M1 plotted against occlusal wear (dentine percent for M1) for the North American and Levant groups



- 7.481 Scatter plot of the approximal facet length (mm) of lower left M1 plotted against occlusal wear (dentine percent for M1) for the North American and Levant groups
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## **Acknowledgments**

I would first like to extend much thanks my supervisors, Professor Simon Hillson, Dr. Arlene Rosen and temporary advisor Dr. Elizabeth Bacus for their patience, experienced advice and unconditional support. Next, I owe much gratitude to Mr. Robert Kurszynisky, Natural History Museum of London, Dr. Michelle Morgan, Harvard University Peabody Museum of Archaeology and Ethnology, Dr. David Hunt, Smithsonian Institution Natural History Museum, and Dr. George Crothers, University of Kentucky W.S. Webb Museum of Anthropology for their advice, knowledge and use of skeletal collections, for this project would not have been possible without them. I would also like to show thanks to Dr. Charles FitzGerald and Dr. Daniel Antoine for help with designing a database, statistical analysis and dental techniques. To my proofreaders, Dr. Penny Howles, Dr. Laurence Owens and Ms. Victoria Green, I owe much to your time and patience for reading my thesis. On a more personal note, to my parents, Tom and Nan, who through out the years have always supported my dreams and ideas. The two of you have given up much for me to follow my heart I owe you both so much, love you. To Josias and Jack, you have always been there to pick me up when things were hard, believing in me and trying to understand my desire to study teeth. Thank you tall Monkey. Lastly, I would like to show my appreciation to my friends (especially the canines, Kylee and Molly) and family, you have always supported and encouraged this dream of mine. Thanks for the numerous emails, phone calls and cards of motivation over the years.

## Chapter 1 — Introduction

This project was designed to investigate the hypothesis that non-agricultural people (subsisting through hunting, fishing and gathering their resources) had a characteristic pattern of tooth wear which contrasted with the pattern of agriculturalists. This idea is of fundamental importance for investigating the origins of agriculture. It has its origins in the work of Robert J. Hinton (1982) who found that a large Archaic group from the Tennessee River Valley differed consistently from a large assemblage of Mississippian remains (also from the Tennessee River Valley) in the rate of wear and its distribution through the dental arcade. Later, Holly B. Smith (1984) also suggested that there was a consistent difference between non-agriculturalists and agriculturalists world wide in the rate at which the angle of the wear facet in molars changed with increasing occlusal wear. To cultural archaeologists this simple division has always seemed unlikely in view of the contrasts between different types of agriculture and variation in the resources available to hunters, fishers and gatherers. In addition, the methods used to record tooth wear are somewhat subjective and probably hide a large amount of additional variability. In both Hinton's and Smith's work arithmetic means were used to represent tooth wear in each of the groups and there has never been any real consideration of the variability of wear scores within groups. The present project therefore, was designed to address these questions by looking at different groups to those originally studied, in contrasting environments, by considering variability, and by applying more sophisticated techniques in the assessment of dental wear.

## Chapter 2 — Dental Anatomy

Before starting the structure of the current project, it is appropriate to summarise and discuss the field of dental anthropology so that the full implications of the techniques used herein can be understood within the wider academic field. This chapter contains a discussion of:

- the components of the tooth
- dental development
- dental eruption sequences
- occlusion
- dental wear
- functional changes teeth undergo from heavy attrition wear.

Throughout the thesis abbreviations have been used which are as follows:

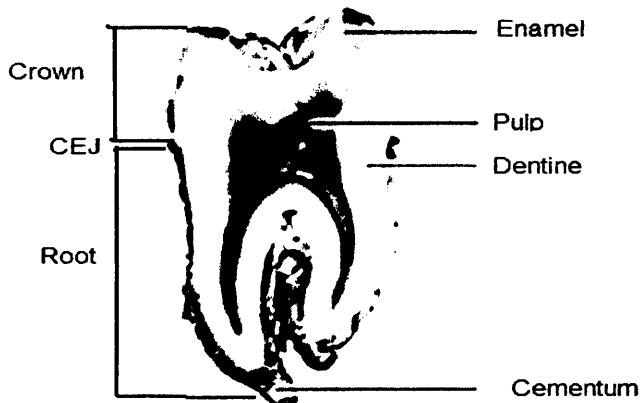
- first incisor = I1
- second incisor = I2
- canine = C
- first premolar = P1
- second premolar = P2
- first molar = M1
- second molar = M2
- third Molar = M3

### 2.1 Components of the tooth

The two main anatomical parts of the tooth are the crown and the root, separated at the cervix by the cemento-enamel junction, or CEJ (Cauvin and Sanlaville, 1981, Hillson, 1996, Schour and Massler, 1940). The enamel coats the crown surface whilst the bulk of the crown consists of dentine. Both enamel and dentine are hard, mineralised materials, while the central pulp chamber contains the soft tissues (nerves and blood vessels) of the tooth. The structure is held in place by the periodontal ligament and a layer of cementum on the tooth root (Figure 2.1). As dental microstructure is central to the current project, each of these materials is described in further detail below.

## Enamel

Fully mineralised enamel is acellular and avascular, has no nerve supply and is the hardest substance in the human body. It is glossy, semi-translucent and can range from white, light yellow to grey-white in colour. Once enamel is formed it can not be replaced or remodelled because the ameloblasts die after formed (Nanci, 2003). As enamel coats



**Figure 2.1: The main components of a tooth (modified from Nanci, 2003)**

the external face of the exposed dentition in life, the manner and rate at which it wears away can be a determinant of the behaviour in archaeological populations.

## Dentine

Dentine is semi-mineralised tissue (brown to yellow in colour) which is softer than enamel – while possessing

greater compressive and tensile strength – but slightly harder than either bone or cementum (Berkovitz et al., 1992, 2002, Scott and Symons, 1974). Dentine cells (odontoblasts) line the inner surface of the dentine, surrounding the pulp chamber, and continue to form secondary dentine after the tooth has developed and erupted. Secondary dentine can be distinguished from primary dentine on the basis of colour; it is dependent on the pulp chamber and root canal, which are eventually filled in by dentine throughout life. Secondary dentine is often seen on the occlusal surface of very worn teeth.

### ***Pulp chamber***

Beneath the dentine is the pulp chamber and pulp canal, which contain arteries, veins, lymphatic elements and nerves (Ash, 1993). The pulp canal passes from the central pulp chamber through the tooth root, allowing the soft tissue structures to connect with their corresponding systems within the mandibular body. The combined soft tissue-filled area of the chamber and canal is referred to as the pulp (Berkovitz *et al.*, 1992).

## Cementum

Cementum is a thin layer of yellowish, bone-like substance that surrounds the root of the tooth (Scott and Symons, 1974). It has two structural components: (1) acellular cementum, which provides attachment for the tooth in the alveolus (tooth socket), and (2) cellular cementum, which responds to tooth wear and movement and is associated with the repair and regeneration of periodontal tissues (Nanci and Somerman, 2003).

## 2.2 Dental development

While the tooth germs are developing in the jaws, bone forms around them to create small 'crypts' which are the formative space for the development of the crown and root. After birth, the roots of the deciduous teeth start to form, propelling the crowns into the overlying tissues until they erupt through the gingivae into the mouth (Hillson, 1996). The roots continue to grow, leading to extensive remodelling of the periodontal ligaments and alveolar bone. There is however, some debate to what really pushes the teeth in eruption. One of the theories is based upon the forces generated beneath and around the tooth (alveolar bone growth, root growth, blood pressure or tissue fluid pressure) to push the tooth out. Another viewpoint is that the tooth is pulled out as a result of tension within the connective tissue of the periodontal ligament (Berkovitz et al., 2002). There are not however, enough studies to be sure as to which theory is *Correct*.

### ***Chronology of tooth development***

While the crowns of the deciduous teeth are forming, the permanent teeth are at the early tooth-germ stage. According to the position of the tooth within the arcade (i.e. if the permanent tooth underlies its deciduous predecessor), the later stages of permanent tooth formation coincide with the eruption – and eventual evulsion – of the deciduous teeth. Because individuals are not exactly alike, the times for tooth development shown in Table 2.1 are approximate. Variations of six months either way are not unusual, although in the majority of cases mis-timed teeth erupt later rather than earlier. There are also some differences between girls and boys, as the former are often relatively precocious in terms of dental development (Berkovitz *et al.*, 2002).



CHRONOLOGY OF DECIDUOUS DENTITION					CHRONOLOGY OF PERMANENT DENTITION				
Tooth	First evidence of calcification (months <i>in utero</i> )	Crown completed (months)	Eruption (months)	Root Completed (years)	Tooth	First evidence of calcification	Crown completed (years)	Eruption (years)	Root completed (years)
Maxillary					Maxillary				
A	3-4	4	7	1 ½-2	1	3-4 months	4-5	7-8	10
B	4 ½	5	8	1 ½-2	2	10-12 months	4-5	8-9	11
C	5	9	16-20	2 ½-3	3	4-5 months	6-7	11-12	13-15
D	5	6	12-16	2-2 ½	4	1 ½-1 ¾ years	5-6	10-11	12-15
E	6-7	10-12	21-30	3	5	2-2 ½ years	6-7	10-12	12-14
Mandibular					6	Birth	2 ½-3	6-7	9-10
A	4 ½	4	6 ½	1 ½-2	7	2 ½-3 years	7-8	12-13	14-16
B	4 ½	4 ½	7	1 ½-2	8	7-9 years	12-16	17-21	18-25
C	5	9	16-20	2 ½-3	Mandibular				
D	5	6	12-16	2-2 ½	1	3-4 months	4-5	6-7	9
E	6	10-12	21-30	3	2	3-4 months	4-5	7-8	10
Unless otherwise stated indicated all dates are postpartum. Teeth are identified according to the Zsigmondy system. A-E are deciduous dentition (A=incisor) and 1-8 (1=first incisor) are adult dentition.					3	4-5 months	6-7	9-10	12-14
					4	1 ¾-2 years	5-6	10-12	12-13
					5	1 ¼-2 ½ years	6-7	11-12	13-14
					6	Birth	2 ½-3	6-7	9-10
					7	2 ½-3 years	7-8	12-13	14-15
					8	8-10 years	12-16	17-21	18-25

Table 2.1: Chronology of tooth development and order of eruption from Berkovitz, Holland, and Moxham (2002).

Moorrees *et al.* (1963a, 1963b) carried out a series of post-natal tooth development studies using archaeological materials. The study was based upon radiographic images and designed to show all three stages of tooth formation (calcification, crown completion and root completion) (Smith, 1991). They developed a method to calculate mean age for 14 dental development stages from cusp formation to root formation. Because the system was based upon simple percentage, completions of crown and root formation, the system is easily applied (Figure 2.2).

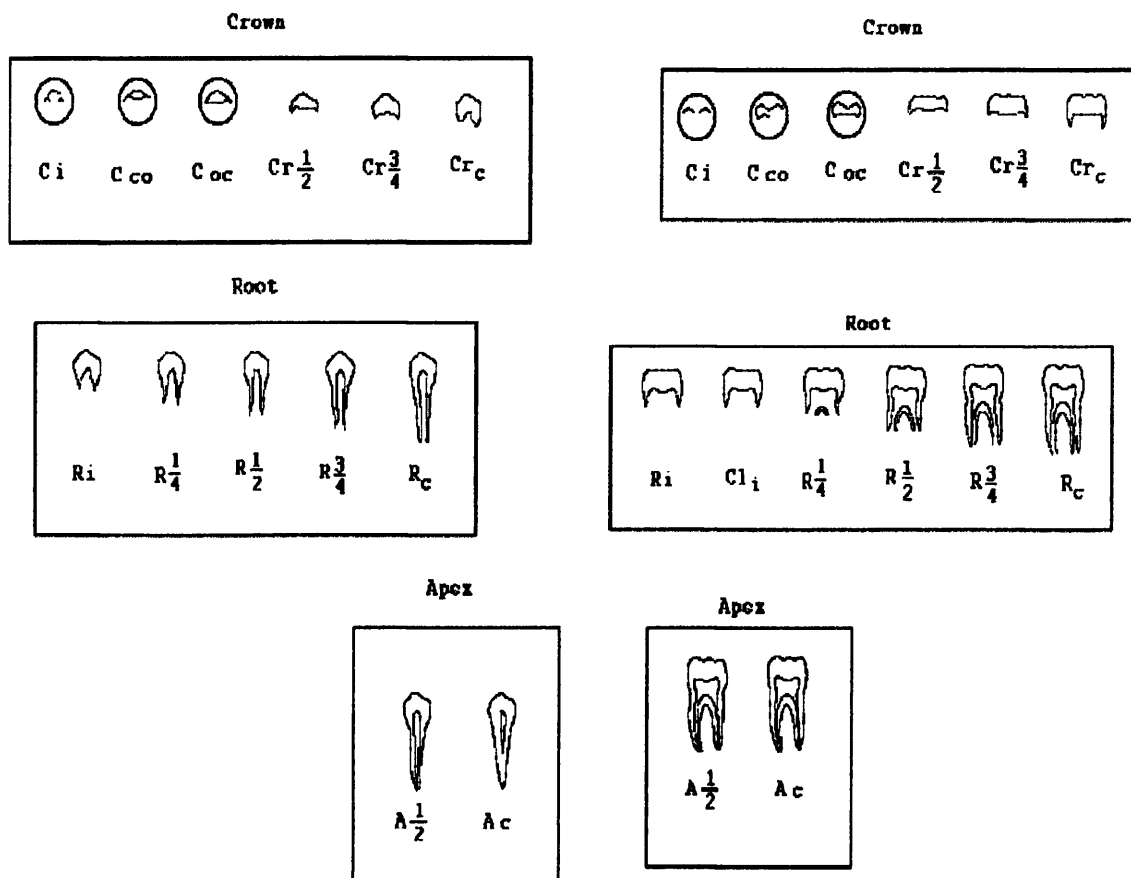


Figure 2.2: Morreess *et. al.* (1963a) cusp and root formation diagrams (drawing adapted from Hillson, 1996).

Another schematic diagram of odontogenesis is reproduced below in Figure 2.3, showing an approximation of the eruption order from *in utero* to anatomical maturity (taken from Schour and Massler, 1941 in Ash 1993). The yellow teeth denote permanent dentition; the blue, deciduous.

The Morreess *et. al.* (1963a, 1963b) method only illustrates the development sequence of individual crowns and roots, while the Schour and Massler (1941) method shows how the teeth inter-relate during the eruptive sequence. These methods can be used in conjunction, but attaining a high level of accuracy necessitates the use of radiographs.

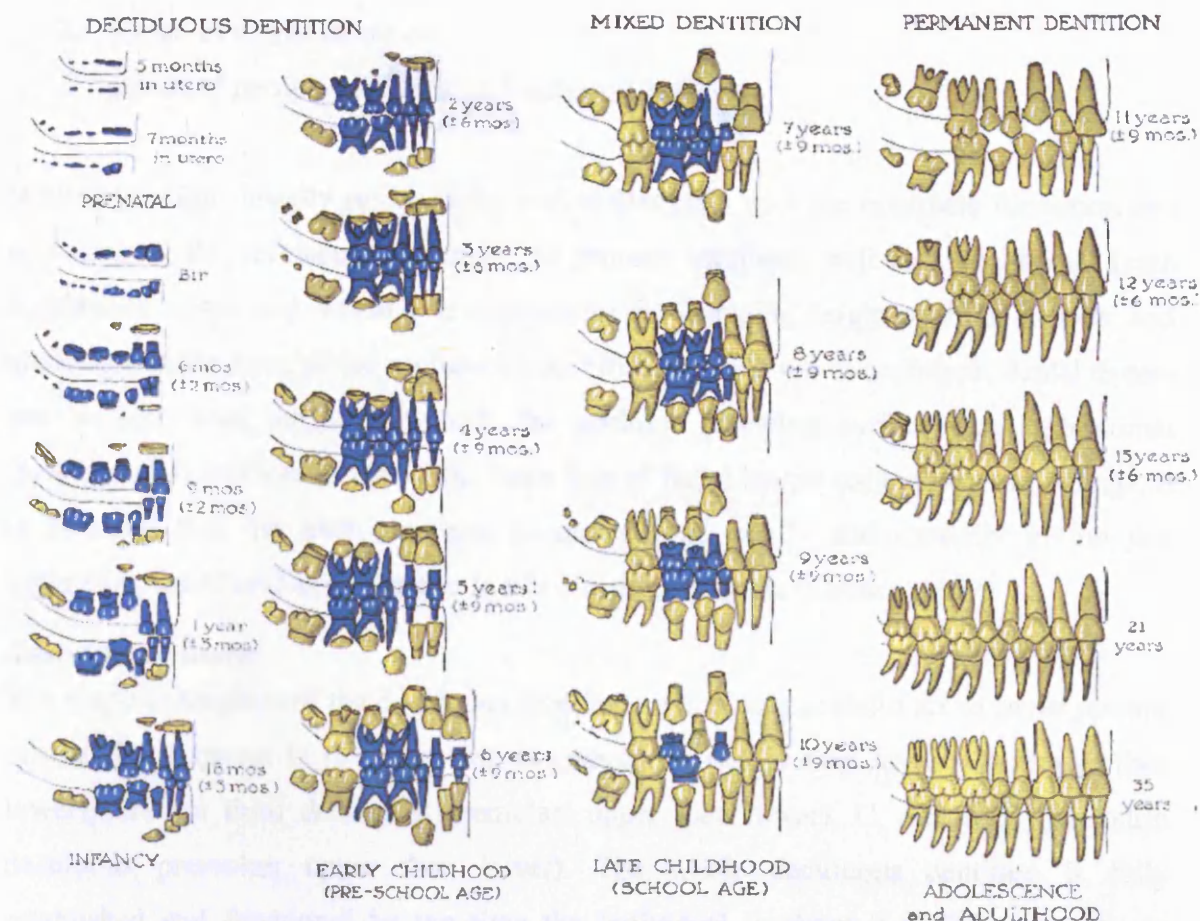


Figure 2.3: Human development of dentition. Illustrations are from Schour and Massler (1941 in Ash 1993).

### 2.3 Dental Eruption Sequences

Eruption is the process by which the tooth crown is forced from its developmental position in the bony crypt to a fully occlusal position in the oral cavity (Osborn, 1981, Ten Cate and Nanci, 2003). Specifically, as teeth develop, the crypt extends through the bone of the jaw to the alveolar apex. As the tooth extends its total length, the bony wall of the crypt's superior aspect gives way to allow the crown of the tooth to emerge through a small window at the alveolar crest. This stage is known as alveolar eruption (Hillson, 1996), which is followed by gingival emergence or clinical eruption. In this section of the process, the bony window widens to permit the emergence of the cusps and, eventually, the whole circumference of the occlusal surface breaks through the gingivae. The next stage in the eruptive process is the entry of the crown into occlusion, which may be judged with reference to the neighbouring teeth or by the first signs of wear. Eventually the occlusal surface abuts the occlusal plane and comes into contact with its antimeres on the opposing jaw, followed by root completion and apex closure (Hillson, 1996). Current interpretations of the timing and sequence of 'dental eruption' are usually based upon gingival emergence. Eruption can be arranged into three periods:

1. period of deciduous dentition
2. period of mixed dentition
3. period of permanent dentition (Hillson, 1996).

While 'eruption' usually refers to the period that ends with the complete formation and occlusion of the permanent dentition, the process continues well into adulthood. Teeth continually adjust and remodel in response to the changing height of tooth crowns, and alterations in the form of the occlusal plane. Once the teeth are in occlusion, dental tissues can be lost from attrition on both the occlusal (chewing surface) and approximal (mesial/distal) surfaces of the tooth. Since loss of facial height only appears in old age, it is assumed that the teeth continue to move both axially and mesially in the jaw throughout adulthood as a response to this attritional process (Osborn, 1981).

### ***Deciduous teeth***

The gingival eruption of the deciduous dentition commences at about six to seven months of age. They appear in the following sequence: I1 (upper then lower), I2 (upper then lower), M1 (or third deciduous premolar; upper then lower), C, and M2 (or fourth deciduous premolar; upper then lower). The whole deciduous dentition is fully established and functional by the time the individual is about 2 to 2½ years of age (Hillson, 1996). From the table and figures above, it is clear that root formation in deciduous teeth is complete in 1 to 1½ years after the tooth appears in the mouth cavity. The formation of each deciduous tooth takes between two and four years from the appearance of the tooth germ to the completion of the root. A completely deciduous dentition is in operation for five to seven years prior to the appearance of permanent teeth.

### ***Mixed dentitions***

During the mixed dentition stage, the deciduous teeth are shed as the permanent teeth start to erupt and move into full occlusion. For the eruption of the permanent dentition, the roots of the deciduous tooth have to be reabsorbed to allow for shedding, a process which is well-documented from a series of radiographic studies (Haavikko, 1973 from Hillson 1996, Moorrees et al., 1963b). Initially, each deciduous tooth and its developing permanent successor share a common alveolar crypt, with the permanent tooth germ situated lingually to the deciduous tooth (Berkovitz *et al.*, 1992, 2002). During the early eruptive stages of the permanent tooth, the bone separating it from its deciduous predecessor is reabsorbed. Following this, the deciduous tooth's hard tissues are broken down by the activity of multinucleated odontoclasts, which have been called the reabsorbing organ of Tomes (Berkovitz *et al.*, 2002).

**Permanent teeth**

Events in the formation of permanent human dentition occur in several phases or clusters (Schour and Massler, 1940 from Smith 1991). M1 and the anterior teeth (I1, I2 and C) all begin formation within the first year of life. The second odontogenetic event begins for P1, P2 and M2 between two and four years. M3 develops comparatively late, some five to six years after M2. The development time of M3 however, is not under strict genetic control and there is considerable variability between human groups (Fanning and Morreess, 1969). Permanent tooth germs develop on the lingual aspect of their deciduous predecessors in the same bony crypt, and migrate during gnathic development. For example, the permanent incisors and canines eventually move to their own bony crypts on the lingual side of their deciduous predecessor's roots. The premolar tooth germs end up directly beneath the divergent roots of the deciduous molars. The permanent molars, however, develop free of occlusal obstruction and mature from the distal extrusion of the dental lamina behind the deciduous molars (Nanci, 2003).

There is considerable variation in both the sequence and timing of tooth eruption, between populations, sexes and individuals. There are also differences between the upper and lower jaws (Hillson, 1996). The upper dentition erupts as follows:

M1, I1, I2, (P1, C, P2), M2

The eruptive sequence of the lower dentition is:

(M1, I1), I2, (C, P1), (P2, M2)

Human dental development is even more diverse in emergence timing. The four main emergence phases are (Smith, 1991):

Phase 1. deciduous teeth, most emerging during the second year of life

Phase 2. permanent M1, I1 and I2 at 6–8 years of age

Phase 3. permanent C, P1, P2 and M2 at 10–12 years of age

Phase 4. permanent M3 at 18+ years of age.

As noted above, eruption sequences between tooth classes may differ slightly. For example, in phase 2 I1 may precede M1. There are more alternative eruption timings in phase 3 due to the large number of the teeth in this phase; the most common are lower P2 then P1, and the upper P2 then M2. There are various mandibular dentition variations, including P2 (or P1) precedence over C, or M2 precedence over P2. The most common occurrence of mistiming in the maxillary dentition is C precedence over P1 (Hillson, 1996).



## 2.4 Occlusion

Once teeth are completely erupted they are considered to be in full occlusion. However, in the event of heavy wear, occlusion can change and modify to adapt throughout life history. This section defines 'normal' occlusion for clinical applications, and for populations with relatively low dental wear.

'Normal' occlusion (Thomson, 1981) is defined as contact between opposing teeth while the mandible is stationary, and refers to the movement and positioning of the occlusal contact areas rather than the individual teeth ('normal' occlusion is also referred to as 'anatomical centric occlusion'). Each arch is bilaterally symmetrical (Berkovitz *et al.*, 2002), although it is customary to include minor variations from the ideal as 'normal' occlusion (Osborn, 1981). Each tooth in the upper dental arch is opposed not only by the corresponding tooth in the lower arch, but also by the tooth directly distal to its antimere, due to the much greater mesio-distal width of the upper teeth. The only exception to this is M3, which only occludes with the lower M3, and the deciduous upper M2 only occludes with the lower M2 (Figure 2.4). These characteristics are also partly attributed to the maxillary arch being broader than the mandibular arch.

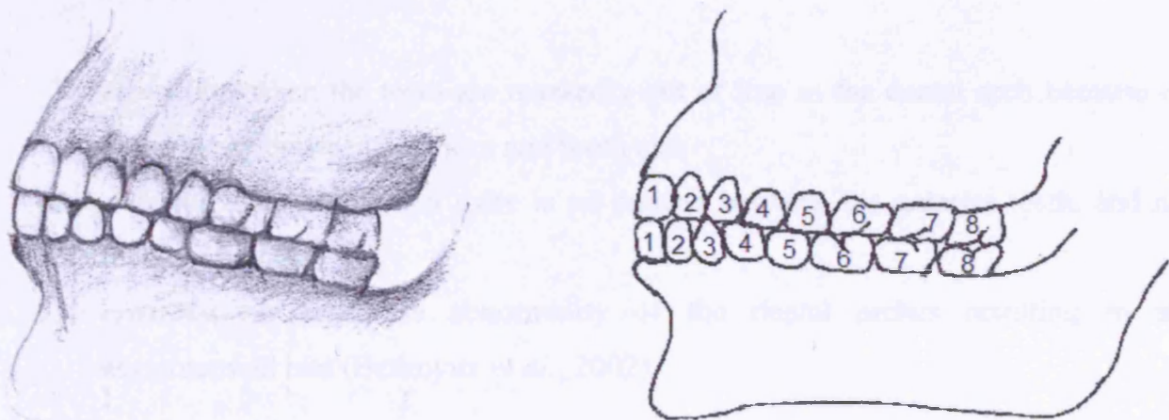


Figure 2.4: Normal (or centric) occlusion. The upper I1 occludes with the lower I1 and lower second incisor, the upper I2 occludes with the lower I2, and lower C, etc. However, the upper M3 only occludes with the lower M3 (1 = I1, 2 = I2, 3 = C, 4 = P1, 5 = P2, 6 = M1, 7 = M2, and 8 = M3). (Drawn by author.)

### **Anatomical alignment of teeth**

The line of occlusion for the maxillary dentition passes through the cinular (a bulbous convexity near the cervical region of a tooth) of the anterior teeth, and through the central fossae of the posterior teeth (Figure 2.5). On the mandibular teeth, this line of occlusion runs along the incisal edges of the anterior dentition and the buccal cusps of the postcanines (Berkovitz *et al.*, 2002).



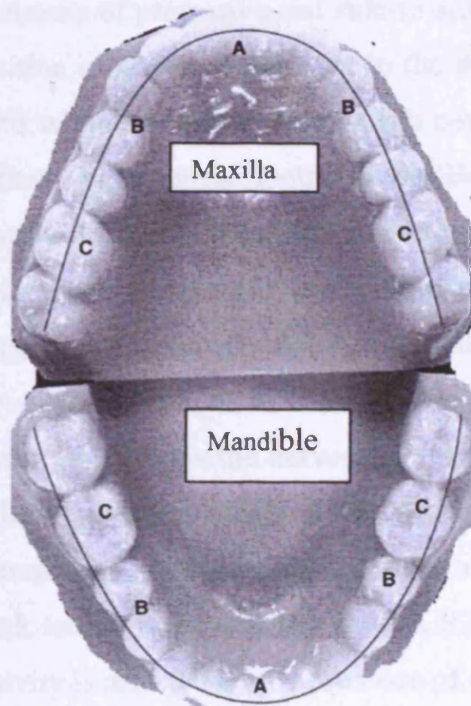


Figure 2.5: Arch of occlusion surfaces. "A" from the maxilla occludes with "A" from the mandible exc. (from Berkovitz *et al.* 2002)

Numerous factors and forces determine the position of the teeth within the dental arch. The configuration of each arch is dependent upon the interaction between the eruptive movements bringing the teeth into occlusion, and the forces subsequently brought to bear upon each tooth (Berkovitz *et al.*, 2002). When fully erupted – continuous eruption (see below) notwithstanding – teeth are inclined relative to the mesiodistal and buccolingual axes, according to their position in the dental arcade (Kraus *et al.*, 1969).

### **Malocclusion**

Malocclusion should be regarded as anatomical variability rather than as an abnormality, as maloccluded teeth are rarely involved in masticatory dysfunction (Thomson, 1981). Three main types of clinical malocclusion are:

1. **crowding**: when the teeth are markedly out of line in the dental arch because of disharmony between arch size and tooth size
2. **anterior open bite**: when there is no contact between the anterior teeth, and no incisor overbite
3. **crossbite**: a transverse abnormality of the dental arches resulting in an asymmetrical bite (Berkovitz *et al.*, 2002).

### **Mastication**

During protrusion (anterior movement of the jaws), retrusion (posterior movement of the jaws) and rotation (jaws move in a circular motion), the post-canine teeth can be kept in contact with one another in order to facilitate food reduction (Scott and Symons, 1974). As the teeth crush the food, the food is passed over the buccal and lingual surfaces, and either the vestibule or the oral cavity proper. Contraction of the buccinators (cheek muscles) and tongue muscles returns the food to the grinding surfaces of the teeth for further mastication (Scott and Symons, 1974).

Mastication can take the form of a chopping, crushing (puncture/crushing) or chewing (shearing) action. In the former, the mandible opens and closes with the

minimum of protrusive and side-to-side movement, with the teeth returning directly to the position of normal occlusion. In the second, the food is crushed and pierced between the teeth without direct tooth-to-tooth contact (this action is thought to be a major cause of attrition wear on the tooth cusps) (Berkovitz *et al.*, 1992). In the lattermost action, the protrusive and side-to-side movements play an important role, where the teeth only returning to centric occlusion at the end of each mastication cycle. This action produces direct scratch lines on the approximal surface (mesial and distal) of the tooth, leading to the development of a facet (Berkovitz *et al.*, 1992). During mastication, inter-tooth contact stimulates the nerve endings of the periodontal membranes, thus regulating, coordinating and modifying the action patterns of the mastication muscles (Scott and Symons, 1974). Chewing is usually carried out on one side at a time, with most of the work taking place between the P1, P2 and M1. The execution of this normal masticatory activity is affected by the presence of caries, ulcers or other painful oral conditions.

## 2.5 Wear

Food rarely contains material particles of sufficient hardness directly to cause attrition wear, although the use of grinding stones may lead to the ingestion of such occlusions (Leek, 1972). Tooth wear can be either dietary or non-dietary. Dietary tooth wear is caused by natural/intentional (i.e. the fibrous elements of the diet) and introduced/unintentional (i.e. sand or grit) abrasives that find their way into the food through preparation techniques (Hinton, 1981, Molnar, 1972, Molnar and Molnar, 1990, Osborn, 1982, Smith, 1984a). Non-dietary wear can be caused by using the teeth as a third hand or as a tool, bruxism (grinding or clenching the teeth together), holding objects between the teeth (such as a pipe), or objects rubbing against the lingual surface of the tooth (e.g. a lip disk).

Two kinds of dental wear are: attrition, and abrasion. *Attrition* is wear produced by tooth-to-tooth contact, which can occur on the occlusal and approximal surfaces. *Abrasion* is a general loss of surface detail from ingested objects that come into contact with the teeth, which is also found on the occlusal and approximal surfaces (Hillson, 1996).

Intuitively, behavioural characteristics, such as food preparation techniques and non-dietary activities (see above), could determine the manner and rate at which each of types of wear (attrition abrasion) forms progresses. Indeed, many studies have shown that occlusal or approximal wear (or dentine exposure (Murphy, 1959b) varies between behavioural groups – such as the heavier wear of foragers when compared to agriculturists – or factors such as inter-sex variability within single populations (Bass,



1995, Benfer and Edwards, 1991, Hillson, 1996, Hinton, 1982, 1981, Kaifu, 2000, Larsen, 1983, 1985, McKee and Molnar, 1988, Molnar, 1972, 1971, Molnar and Molnar, 1990, Molnar et al., 1983, Richards, 1985, Richards and Brown, 1981, Richards and Miller, 1991, Schmucker, 1985, Smith, 1984a, 1984b).

### **Attrition**

Tooth wear begins as the teeth emerge and come into full occlusal contact. Wear of the enamel on the incisal edges and occlusal surface is followed by exposure and wear of the dentine, prompting the laying-down of secondary dentine by the pulp tissues. Occlusal and approximal wear can lead to changes in profile and surface area, as well as a reduction in crown height and width (Barrett et al., 1998, Begg, 1954).

The eruption sequence affects the severity of attrition wear, as early-erupting teeth are inevitably more worn than teeth that erupt later (Molnar and Molnar, 1990). For example, M1 is positioned in the occlusal plane before M2, and will therefore possess a higher level of occlusal attrition than M2. The essentially immutable characteristics of this wear process led Smith (1972) to propose that wear levels could be used to calculate rates of dental attrition, therefore enabling educated guesses to be made about ancient behaviour (Scott, 1979). Once the effect of eruptive phasing (i.e. the amount and rate of wear are attributed to differences in eruption time) has been calculated, some measure of dietary abrasiveness can be derived from the level of wear per tooth. For example, as M2 erupts approximately six years after M1; M1 will therefore possess six years' worth of occlusal wear by the time M2 erupts (Benfer and Edwards, 1991). In a series of similar studies, Miles (1962, 1963, and 1978) correlated attrition wear with the dental eruption sequence, thus refining earlier work and producing a table showing gradients of wear that have serious implications for age calculation and the determination of dietary regime.

### **Attrition wear on the occlusal surface**

When the tooth is in full occlusion, the occlusal surface starts to wear away, thus changing the size and shape of the crown (Kieser, 1990). Each tooth wears in a different manner, according to tooth class, morphology and position in the arcade.

Incisor attrition wear starts at the tip, wearing down the crown to leave a smooth incisal edge. A small line of dentine is exposed along the length of the crown tip, becoming increasingly broader until only the enamel rim is left surrounding the dentine. The rim is eventually worn away, followed by the body of the tooth, wearing down to the root of the tooth (Hillson, 1996).

Canine attrition wear starts at the tip of the main cusp, followed by wearing away of the mesial and/or distal ridges of the incisal edges down to the dentine. Heavier wear

sees the destruction of the main labial bulge of the central cusp, the lingual buttress and marginal ridges. As the wear nears the cervix of the tooth, the exposed dentine assumes the shape of a diamond, with a slightly raised enamel rim. In the final stages of wear, the enamel rim is worn down to the root (Hillson, 1996).

There are significant differences between the standard wear patterns of the upper and lower premolars. Upper premolar attrition wear is initiated at the cusp tips, exposing a small dot of dentine on the buccal cusp, followed by the lingual cusp. After both cusps are worn away, the crests of the marginal ridges are broken down, thus joining the dentine patches and leaving a peninsula-like area of enamel in the centre of the tooth. This 'peninsula' is gradually worn away to an 'island', which eventually becomes a softer dentine area surrounded by the enamel rim. In the final stages of attrition wear, the enamel rim is worn away as the attrition wear moves down the roots of the tooth (Hillson, 1996). Lower premolar wear starts in a similar fashion, the first point of wear being the high point of the buccal cusp, followed by the lingual cusp. Trails of dentine appear as the crest ridges are breached. Finally, only the rim of enamel remains with a dished area of dentine in the centre of the occlusal surface. In extreme cases of attrition wear, the enamel rim is worn down to the roots of the tooth (Hillson, 1996).

Like the premolars, there are notable differences between wear patterns in the upper and lower molars. In the former, dentine is first exposed on the mesio-lingual cusp, followed by the buccal and disto-lingual cusps (although this order is sometimes altered). Lingual wear tends to proceed rapidly until the remaining enamel between them is breached, leaving a small area of enamel in the centre of the crown. This 'island' is slowly worn away until the whole occlusal surface is dentine, with a slight enamel rim. This enamel rim eventually breaks down, as the attrition wear reaches the cervical margin and, finally, the roots. The lower molars wear slightly differently, with the mesio-buccal cusp wearing first, followed by the disto-buccal cusp and then the lingual cusp. The buccal cusps wear down faster; the enamel between them is eventually worn away to expose a patch of dentine. The enamel between the lingual and buccal cusps wears away next, leaving an enamel area midway along the lingual side. This soon gives way to expose a dished area of dentine with an enamel rim, which eventually wears away, followed by the roots of the tooth (Hillson, 1996).

#### **Attrition wear on the approximal surface**

Approximal attrition is the result of a progressive increase in dental contact areas (Kieser, 1990), caused by small movements between pairs of neighbouring teeth (Whittaker *et al.*, 1987). It is not usually as severe as occlusal attrition wear, and rarely reaches the dentine

layer across the width of the facet (Barrett *et al.*, 1998). Approximal attrition usually takes the form of a small facet in the dental contact area; however, the facet is difficult to see when the teeth are still in the jaw, and measuring its dimensions is therefore somewhat difficult. The facet can be measured with reference to total size (breadth), positioned with reference to the occlusal surface (Hinton, 1982). When the tooth is removed from the jaw, the facet can be seen as a small oval of polished enamel on the approximal surface. The facet is usually measured at its widest breadth, but a study by Whittaker (1986) highlighted the possibility of several different shapes and sizes to this facet, although this assertion has not received statistical support.

The second method of measuring approximal attrition involves calculating the reduction of the dental arch (Begg, 1954, Murphy, 1964, van Reenen, 1992, Wolpoff, 1970). Begg claimed that approximal attrition was the main cause of the teeth moving mesially in the jaw, and proposed that approximal attrition wear creates more room in the postcanine area, thus making room for M3 to move into occlusion. However, Begg's theory was discredited by Kaul and Corruccini (1992), who pointed out that even when generous margins were imposed, much of Begg's theory did not stand up to rigorous scrutiny.

### **Abrasion**

Abrasion describes the process by which dental surface detail is lost through contact with abrasive particles in the mouth, notably from food. Foreign objects that come into contact with the teeth – such as toothpicks, clenching a pipe between the teeth, blades or jewellery – can also cause abrasion (Dumond, 1977, Hillson, 1996). Abrasion tends to be more pronounced in archaeological specimens than in modern populations, due to various dietary, food preparation and behavioural characteristics.

Paramasticatory activities resulting in tooth abrasion include the use of teeth as tools, the chewing/reduction of gums or leaves, and chewing/preparation of animal skins (Molnar and Molnar, 1990). Task-related or non-food-related activities resulting in occlusal abrasion are culturally specific (Molnar, 1972), although certain dental abrasion patterns are quite widespread. Most culturally linked dental abrasion is focused on the anterior rather than the postcanine teeth. Common markers include; incisor/canine labial rounding caused by using the teeth as a third hand for activities such as pulling or stripping sinews (Hinton, 1981), interproximal grooving, which may indicate the use of a probe to dislodge food from between the teeth (Brown and Molnar, 1990, Formicola, 1991, Frayer, 1991, Frayer and Russell, 1987, Lukacs and Pastor, 1988, Molnar, 1972, Schulz, 1977, Ubelaker *et al.*, 1969, Wallace, 1973, Whittaker, 1986, Wolpoff, 1970), and

anterior teeth occlusal grooving that is believed to represent processing of grasses or sinews by pulling them across the occlusal surface (Larsen, 1985, Molnar, 1971).

It is difficult to differentiate attrition from abrasion wear, as both are often partially responsible for general loss of the enamel surface (both occlusal and approximal surfaces). For example, when holding an item between the teeth (such as a pipe) the upper and lower molars are in contact (attrition) while I2, C, and P1 are in contact with the pipe (abrasion). In the current project, in order to avoid confusion, the term 'attrition' is used to describe both tooth/tooth and foreign object/tooth wear.

## 2.6 High wear occlusion

Dentition demonstrates adaptation to heavy attritional wear on the occlusal and approximal surfaces, constantly modifying its own functional morphology as a response to severe attrition wear (Kaifu *et al.*, 2003). Begg (1954) stated that 'attritional occlusion' – occlusion that changes according to *in vivo* attritional tooth reduction and tooth migration – was the 'anatomically and functionally correct occlusion of humans' (Begg, 1954 pg 299). He proposed that the failure to develop a full occlusal attrition pattern was the primary cause of dental pathology in non-agricultural groups. According to Begg (in Kaifu *et al.*, 2003), the central characteristics of attritional occlusion include:

- notable tooth-to-tooth contact (attrition)
- friction of exogenous material against tooth surfaces (abrasion)
- chemical dissolution of tooth surfaces; i.e. highly acidic diets (erosion).

These different types of wear may occur simultaneously or separately, but all result in the loss of tooth structure.

Beyond a certain level of severity, attrition wear can affect 'normal' occlusion (Corruccini, 1999, Corruccini and Whitley, 1981, Corruccini *et al.*, 1983, Corruccini and Lee, 1984, Corruccini *et al.*, 1990). Most of these studies – which surveyed samples of Australian aboriginals – assert one common point: the change in diet-linked occlusal function was probably due to the deterioration of occlusion in younger individuals, who were raised on refined commercial foods rather than the traditional diets of their elders. In line with erratic dietary regimes, it was found that dental occlusion was significantly more variable in the younger adult group. (This will be discussed further in the following chapter, Dental Literature Review.) Kaifu (2000) suggested that direct consequences of tooth wear were:

- mesial drift
- incisor lingual tipping (not well documented)
- continuous eruption.

### **Mesial Drift**

*Mesial drift* describes the towards-midline migration of individual teeth, rather than whole-dentition displacement as part of the skeletal growth process. This movement towards the medial line obviates the appearance of approximal spaces between the teeth. Various studies (Fisherman, 1976, Hylander, 1977, Nara et al., 1998 in Kaifu 2000, Wolpoff, 1970) have described mesial drift in diverse populations; there is general agreement that it may occur in both developing and established dentitions.

### **Lingual tipping**

*Lingual tipping* of the anterior teeth refers to the physiological uprighting movement of the incisors (Kaifu *et al.*, 2003). This has not been studied to the same extent as mesial

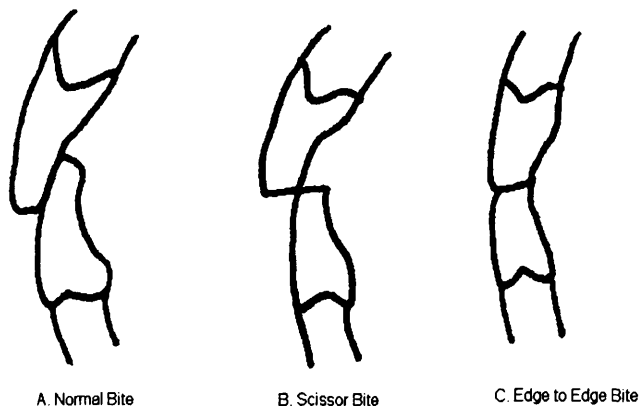


Figure 2.6: Diagrams of normal (A), scissor (B) and edge-to-edge (C) occlusion (Drawn by author).

drift or continuous eruption, but is an important example of heavy occlusal attrition wear patterns in the anterior teeth (Kaifu *et al.*, 2003). Kaifu (2000) suggested that humans may have undergone a transition from scissor occlusion to edge-to-edge occlusion (Figure 2.6). Populations in heavy wear environments generally show

scissor occlusion during the mixed dentition period, but this is modified to edge-to-edge contact in adults, especially as occlusal wear increases. This then leads to lingual tipping of the incisors. Studies (Hinton, 1981, Kaifu, 1999) have suggested anterior tooth wear decreases markedly, associated with changes from a non-agricultural to agricultural lifeway.

### **Continuous eruption**

*Continuous eruption* keeps the dentition in full occlusion throughout life; as the occlusal surface is worn away, the teeth continuously push into the oral cavity to stay in proper occlusion with the opposing jaw. After the dentition has erupted and moved into full occlusion, the teeth shift during adolescent years in order to adjust to facial growth

(Steedle and Proffit, 1985). Between the ages of 11 and 16 years, the occluded teeth begin a second phase of active eruption which is characterised by an increase in lower facial height. This is caused by additions to the alveolar height (Bjork and Skieller, 1972), accelerated growth of the facial tissues (Ekstrom, 1982) and lengthening of the masticator (chewing or cheek) muscles (Steedle and Proffit, 1985). This eruptive growth spurt slows as the face reaches maturity, a relative equilibrium being reached at about 18 years of age (Darling and Levers, 1975). The process of continuous eruption technically constitutes an intrinsic eruption mechanism, designed to compensate for tooth wear and/or continuing vertical jaw growth (Whittaker et al., 1982, Whittaker et al., 1985, Whittaker et al., 1990).

Adult occlusal equilibrium is an ongoing process, in that there are constant small changes in lower facial height as a response to continued eruption. Radiographic studies (Israel, 1973) have shown that a gradually decreasing eruptive rate continues to compensate for facial growth into the 30's and 40's, and in some cases into the 60's. A study by Murphy (1959b) noted a decrease in vertical face height in specimens with marked occlusal wear, which, on closer examination showed that the tooth eruption compensated for only 60% of the attrition. More recent studies (Danenberget al., 1991, Darling and Levers, 1975, Levers and Darling, 1984, Newman, 1999, Whittaker et al., 1985, Whittaker et al., 1990) have suggested that in individuals with moderate tooth wear, the vertical tooth movement was equalled by the loss of the tooth structure.

Darling and Levers (1975) stated that the inferior alveolar canal (which runs longitudinally through the mandible) is a fixed line that can be used as a base line for alveolar crest-to-tooth measurements. Using this method, Newman and Levers (1979) found that the alveolar bone and the inferior alveolar canal maintain a constant relationship to one another, but it is the teeth that move. This mobility has been interpreted as a continual eruption process, in which the teeth continue to erupt in order to compensate for occlusal wear (Whittaker, 1986). Levers and Darling (1984) noted that continuous eruption is not an inevitable process; this process only takes place when the occlusal surface is affected by severe attrition. Glass (1991) carried out a related study of an Irish pre-industrial assemblage, from which he concluded that continuous eruption was more marked in the mandible than the maxilla.

### ***Occlusal planes***

In normal or low attrition wear there are several occlusal plane curves that can be easily seen with the naked eye. These include the curve of Spee, the Monson curve and the Helicoidal plane. Each of these phenomena is related in some way to the mechanics of mastication and wear, and therefore merit individual discussion (see below).

### The curve of Spee

The curve of Spee (Figure 2.7) denotes the tendency for the teeth to align themselves in such a manner that the occlusal plane describes a relatively linear curve in the antero-posterior direction (Kraus et al., 1969, Berkovitz et al., 2002). However, heavy occlusal attrition can cause alterations to the occlusal planes. Sengupta *et al.* (1999) stated that there was a tendency for the molar curve of Spee to reduce with increasing wear; in heavily worn specimens, therefore, this curve becomes less noticeable (Begg and Kesling,

1977).

### The Monson curve

The Monson curve (or transverse curve) describes the relative concavity of the upper molars and the corresponding convexity of the lower molars (Figure 2.8), a condition that is exaggerated by heavy occlusal wear. In unworn dentitions, the lower molars tend to tilt towards the lingual side (Figure 2.8), while the tooth gradually becomes flat then starts to face

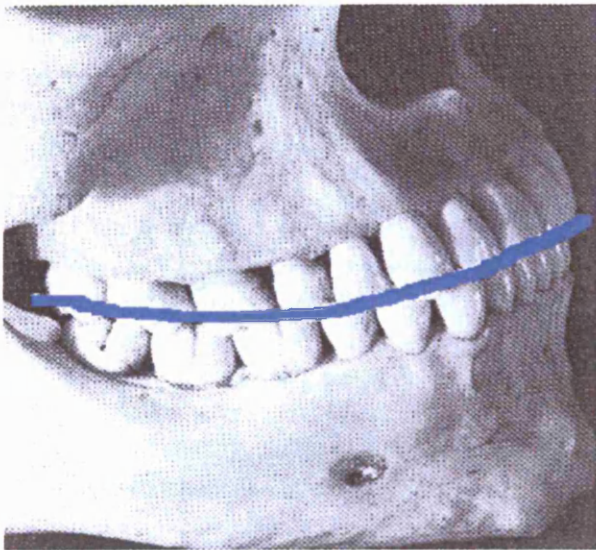


Figure 2.7: The curve of Spee is represented by the blue line (from Berkovitz et al. 2002)

buccally with increased occlusal wear (Osborn, 1982, Richards and Brown, 1986, Tobias, 1980). In a review of various human populations, Richards and Brown (1986) showed that this reversal of occlusal surface orientation was caused by unbalanced wear between the lingual and buccal cusps.

### The helicoidal plane

The helicoidal plane – which can be observed by looking along the occlusal surface of the teeth – describes the increasing axial inclination of the molars from M1 to M3 (Kaifu *et al.*, 2003). According to the position of the teeth, differing extents of inclination have been observed in both worn and unworn teeth. Distribution of wear often conforms to specific patterns (Murphy, 1959a), such as when the canine lingual tubercular ridges wear more rapidly than the buccal cusps, or an oblique slope forms from the buccal to lingual side of the maxillary teeth (the exact reverse is true for the mandibular teeth (Molnar and Molnar, 1990). This pattern starts developing early in the attrition process; the helicoidal plane becoming more distinct with increased wear (McKee and Molnar, 1988).

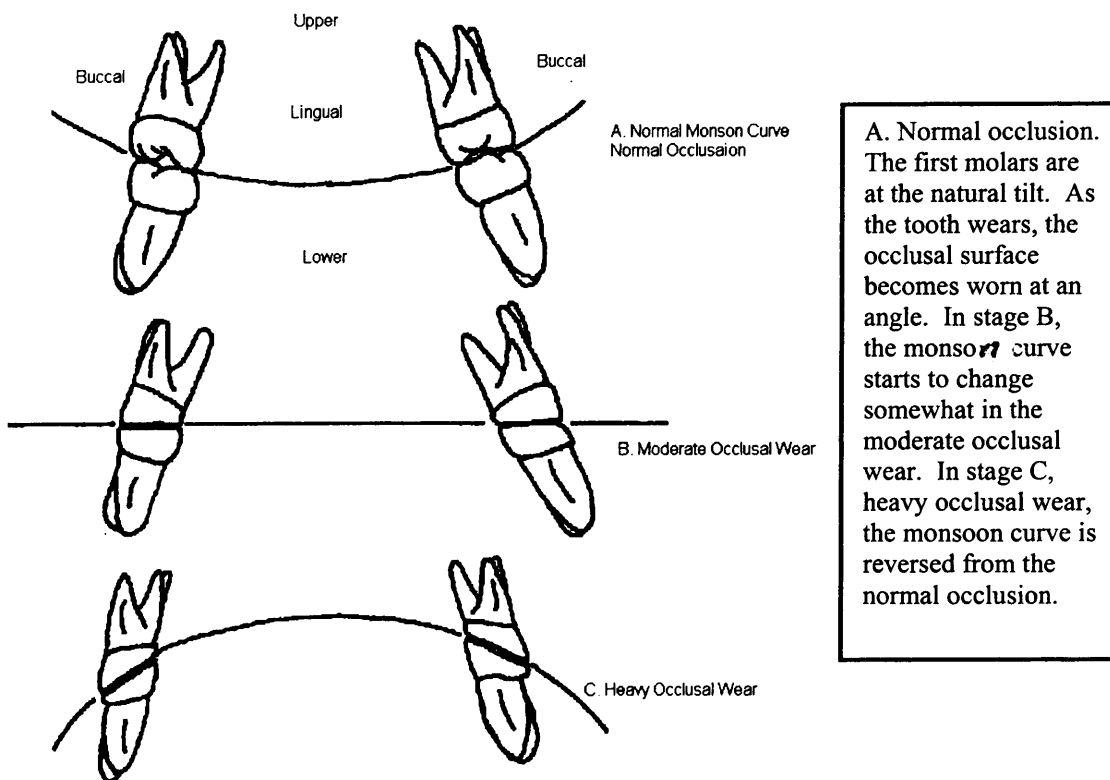


Figure 2.8: Monsoon curve from normal occlusion to occlusion with heavy attrition wear (adapted from Osborn 1982, redrawn by author).

## Summary

This chapter reviewed:

- dental anatomy where the enamel, dentine, pulp and cementum were described
- tooth development section discussed the chronology of tooth development and some of the methods used in archaeology today
- tooth eruption sequence and the three main stages, deciduous, mixed dentition and permanent dentition and the variations of eruption timing
- normal- to low-occlusion wear
- the different types of dental wear, and the difference between attrition and abriasion
- heavy attrition wear, and the changes in the occlusion – along with adaptations that the teeth make to continue functioning in high wear situations (continuous eruption, mesial drift, and heavy wear occlusion).



## Chapter 3 — Dental Literature Review

The aims of this chapter are to:

- explain why teeth are an important asset to archaeology
- describe why attrition wear can be used to examine the transition from non-agriculturalists to agriculturalists
- critique relevant studies in this area of research

### 3.1 Teeth in archaeology

Teeth hold a plethora of social and biological information that is often overlooked. They are unique in that they develop in a predictable pattern, are formed incrementally, do not remodel during life, and have unique metabolic demands during formation (Simpson, 1999). Due to this, teeth are a major source of information for evolutionary anthropologists, archaeologists and forensic experts (Kieser, 1990). This section discusses:

- the quality of dental preservation in the archaeological record
- how teeth are used for estimation of age-at-death
- how dental wear patterns can vary between and within populations.

#### ***Preservation of teeth***

In archaeology it is not uncommon to find that isolated human teeth resist the taphonomic process better than the rest of the skeleton, thus they are often the best-represented remains on archaeological sites (Scott and Turner II, 1997). This is mainly attributed to enamel composition as their subsistence evolutionary histology has led to an extreme degree of hardness, density and calcification (Kelly and Larsen, 1991). For the most part, enamel is usually unaffected by diagenesis under most burial conditions (Bell et al., 1989, Hillson, 1996). It is recognised however, that enamel can suffer postmortem degradation when the soil is very acidic, however some organic remnants of the dentine may survive (Hillson, 1996, Poole and Tratman, 1978, Stead et al., 1986). Distinguishing ante-mortem wear from post-mortem wear, usually relies on the colour and texture of the enamel (Child, 1995). If the enamel is rough, or shows an irregular surface, this was probably due to the diagenesis, however, if the enamel surface is cracked and dull this is most likely due to cremation (McKinley and Roberts, 1998). The crown of the tooth can sometime crack or break (but not be associated with cremated remains, but by

mishandling or poor storage). Enamel damage can be identified as ante-mortem wear when the crack or break is a clean break and often a different colour (usually whiter) than the rest of the crown.

### **Age-at-death estimation**

Infant and juvenile age can be estimated from dental development and eruption. As an infant's jaw develops, the eruption of the deciduous and adult dentitions can give an accurate age-at-death. Studies by Liversidge (1994, 1998) tested the accuracy of age estimation on known aged children from the Spitalfields collections and found that some methods were more accurate than others. However, establishing adult age-at-death is not as exact, because age-at-death cannot be based on dental eruption or development as in children. On the other hand, in adults, the occlusal wear increases with age (Butler, 1972). Therefore determining the age from the degree of wear, teeth can therefore provide a vague approximation of age-at-death. Unfortunately since populations wear their teeth at different rates (Molnar, 1972), it is often necessary to supplement this approach with other age estimation methods such as the pubic symphysis or auricular surface (Walker et al., 1991).

Dental wear is culturally specific and certain patterns are unique to particular populations (Molnar, 1971a, 1972). Miles (1963) developed a technique for determining the age-at-death based on dental wear, which he tested on an assemblage of early British material, and then successfully applied to other collections (Brothwell, 1981). In many populations, age-related trends tend to be obscured by variations caused through occupational exposure to grit, as well as idiosyncratic local influences such as bruxism. Since these characteristics differ from population to population, one cannot be sure that each group will have the same rate of wear.

This problem has been exhaustively assessed. For example, Tomenchuk and Mayhall (1979) examined cusp height related to the age in living Inuits, and correlated the level of tooth wear with the chronological age of the individual. Differences in bruxism, particularly in the posterior teeth, may have been the mechanism responsible for the measured differences in the cusp height. In contrast, a study by Richards and Miller (1991) showed a high correlation between tooth size, wear facets and age amongst young aboriginal Australians. Despite the variability in the extent of tooth wear at various ages, the gradient of occlusal surface wear correlated with age, suggested the possibility of using wear scores to estimate age. Molnar *et al.*, (1983) were able to classify most individuals correctly into both age and sex groups on the basis of their attrition patterns. In both of these studies it was suggested that attrition wear was a good indicator of age,

but abnormal heavy wear can render age estimation inaccurate (Hillson, 1996). It is therefore important to recognise the type of population being assessed, and dental wear should not be used on its own age-at-death estimation.

Another increasingly utilised ageing method is examination of incremental enamel layers in developing dentitions. Counting enamel layers on known-age juveniles was proven to be an efficient, yet difficult ageing method. A study by Antoine *et al.*, (1999) showed that counting these microscopic structures gave an accurate for age-at-death in juveniles whose teeth were still developing. However the use of such methods is very time consuming, and in any case can only be used in developing dentition (Fitzgerald and Rose, 2000).

### ***Variations of dental wear within or across populations***

Tooth wear provides information on many additional aspects of human behaviour such as:

- diet and food preparation techniques
- activities involving the teeth used as a tool (paramasticatory activity)
- health and nutritional stresses within a population.

Most prehistoric peoples consumed tough, grit-contaminated foods (Smith, 1972) which caused rapid tooth wear. The correlation between chronological age and severity of attrition was therefore strong. For example, Smith (1972, 1989) stated that the diet and preparation of food in the Natufians was the major cause of the heavy tooth wear and low prevalence of caries. In general, there is a gradient between abrasive diets which produce rapid wear on the occlusal surface, and a softer diet with a high carbohydrate content associated with caries and periodontal disease (Smith, 1991). Today, modern western peoples consume soft, grit-free foods, and have a higher prevalence of caries. As a result, dental attrition is slow and wear rates are difficult to measure (Larsen, 1995, Walker *et al.*, 1991). The use of teeth as a tool or as a third hand may be unique to a particular population (Molnar, 1971a, 1972, Teafor, 1991). Some studies have shown evidence of the anterior teeth being labially rounded due to holding an object in the anterior teeth while pulling the object downward with the hands (Milner and Larsen, 1991, Molnar, 1971a, 1971b). The overall health, diet and nutritional stresses of a population can be determined by examining the dentition (Duray, 1996, Hillson, 2000, Smith, 1972) particularly caries, which has been the primary focus of studies in many agricultural groups (Hillson, 2000, 2001, Merbs and Miller, 1985, Schumucker, 1985, Sciulli, 1997, 2002, Turner II and Cheuiche Machado, 1983, van Reenen, 1966). The information that

can be obtained from such studies is of great social significance. For example, Larsen (1983) suggested that females had a higher rate of caries because they were responsible for agricultural- related activities including food preparation, while the males were still responsible for hunting and had more dietary reliance on meat.

### **3.2 A study of attrition wear**

Wearing away enamel and dentine was once often described as a pathological condition, but is now accepted as a natural biological process due to the marked occurrence of dental attrition among prehistoric populations and modern groups (Molnar, 1972). In Chapter 2 Dental Anatomy, dental attrition was described as the result of complex interactions between teeth, their supporting structures, and the function of the chewing apparatus. If attrition is a normal by-product of human interaction with certain aspects of their environment, then a study of tooth wear patterns should provide a record of past activities (Molnar, 1972).

Past studies have demonstrated that populations may participate in different activities, and therefore shown different attrition patterns. This was most clearly seen in comparisons between hunter-gatherer and agricultural groups (Hinton et al., 1980, Hinton, 1981, Kaifu, 2000, Lalueza et al., 1996, Larsen, 1983, Lukacs, 1996, Molnar, 1971a, Richards, 1985, Smith, 1995, Smith, 1984a, Smith, 1989, Turner II, 1979, Turner II and Cheuiche Machado, 1983, Walimbe and Lukacs, 1992, Walker and Erlandson, 1986). Tasks, such as food preparation, diet and paramasticatory activities are the main behavioural elements that vary between populations (see above). Attrition rates can also be used in studying diet, as diets with gritty or sandy foods cause heavy attrition wear and diets that are soft and refined cause little wear (Smith, 1984a, Smith, 1972, Teaford, 1991). Task-related dental wear (non-food-related activities) may cause unique dental wear patterns. For example, grooves found on the occlusal surface of Inuit anterior teeth derive from pulling sinews over the tooth surface (Molnar, 1972, Pedersen, 1947, Schulz, 1977), or the preparation of willow fibres for the construction of basket ware (Larsen, 1985).

Attrition wear can also be used to indicate sexual division of labour when males and females carry out different tasks within the population (Molnar, 1972). Therefore, wear studies can also contribute to the emerging discipline of archaeological gender studies. The relative importance of each of the factors (diet, food preparation techniques or non-food-related wear) to dental wear is debatable, but it can, nevertheless, be said that all these characteristics contribute to the attrition wear patterns.

### 3.3 Previous research

Over the years, various projects have contributed to the study of dental attrition wear. Some researchers have investigated the behavioural differences between groups (Behrend, 1977, Brown and Molnar, 1990, 1982, 1972, Hinton, 1981, Molnar, 1971a, Smith, 1981, 1984b, 1986, Walker and Erlandson, 1986), or populations (Dahlberg, 1963, Duray, 1996, Pedersen, 1947, Schumucker, 1985, Sciulli, 1997, Tomenchuk and Mayhall, 1979, Turner II and Cadien, 1968). Published studies of Archaic Native Americans from the Tennessee River Valley (Hinton, 1982), aboriginal Australians (Hinton, 1981, McKee and Molnar, 1988, Molnar and Molnar, 1990), San Bushmen of Southern Africa (van Reenen, 1992), and Greenland Inuits (Pedersen, 1947) all suggested that hunter-gatherers have characteristic patterns of wear that are very distinct from those of agriculturists.

Although patterns vary between big-game hunters and broad-spectrum foragers, regarding differences in diet and paramasticatory activities, they all share common features (relative to agriculturalists):

- high occlusal wear rate relative to age
- a strong gradient of occlusal attrition with highest rates in the anterior teeth and lowest in the posterior teeth
- heavy approximal wear for any given occlusal wear stage
- slow rate of change in the angle of the occlusal wear on the molars per stage of occlusal attrition.

The exact reasons for these features are not fully understood but have been discussed by Molnar (1971a, 1972), Hinton (1981, 1982), Smith (1984a) and Molnar and Molnar (1990), amongst many others. Current hypotheses suggest that the wear patterns may have been due to diet, to non-dietary uses of teeth and the preparation of hunted and gathered foodstuffs.

Much research has been carried out on central Australian aboriginals from the Yuendumu settlement camp. The theory of tooth length reduction through approximal wear was first introduced by Begg (1954). Kaul and Corruccini (1992) refined this study by examining how the mesio-distal tooth length was reduced by approximal wear due to the heavy occlusal wear. However, it was thought that Begg judged the approximal wear to be greater than it actually was. Kaul and Corruccini stated approximal wear was present in the Yuendumu aborigines but not to the severe degree that Begg claimed.

McKee and Molnar (1988) also investigated differences in dental wear within the Yuendumu settlement camp, where it was noted that certain group-specific behavioural

factors needed to be considered. The individuals from this population were subsisting on modern western food, where the primary oral abrasives were introduced through traditional food preparation techniques (McKee and Molnar, 1988). The results from this study presented four different patterns of occlusal wear, attributed to variations such as age-at-death, sex estimation, dental eruption sequences and dietary content.

Molnar and Molnar (1990) worked on the theory that the dental arch shape was a factor that contributed to heavy occlusal wear, and that the tooth wear frequently reported among certain Yuendumu Australian aboriginal populations was due to dietary abrasives. Individuals in this group originally subsisted on more abrasive diets then, later in life, soft diets. They spent the first part of their lives living a traditional aboriginal lifestyle, incorporating hunting and gathering food, as well as processing and preparing food in traditional methods. When they were moved to the Yuendumu settlement camp, their diets and food preparation techniques became westernised (Molnar and Molnar, 1990).

To demonstrate their theory, Molnar *et al.* (1983) investigated the children who had spent their entire lives at the Yuendumu settlement camp. The children's diet was considered modern, with few abrasives. The rate at which their teeth wore was not as severe as for the adults, who had a more abrasive diet before moving to the settlement camp. Tooth surface wear was also shown to correlate with the sex of the individual. It was suggested that females wore their teeth at a significantly higher rate than the males, and that the mandibular molars wore more rapidly than maxillary molars (Molnar *et al.*, 1983). Both groups developed wear at the early stages in life, but wear progressed more rapidly for those people who had spent at least part of their lives on a traditional aboriginal diet. Molnar and Molnar (1990) concluded that if they could control for diet, tasks and age as independent variables, the degree of influence that these variables had on tooth wear could be more accurately assessed.

The Australian aboriginal dental research reviewed here resemble various other studies, (Brown and Molnar, 1990, Everly *et al.*, 1998, McKee and Molnar, 1988, Richards, 1984, 1985, 1990, Richards and Brown, 1981, Richards and Miller, 1991) which shared common features. The degree and severity of attrition:

- was relatively high on the occlusal surface
- showed greater wear on the approximal surface in the populations with a traditional aboriginal lifeway
- showed greater wear on the occlusal surface in females than males.

It is important to note that some of the individuals studied started out living a traditional aboriginal lifestyle, then moved to the Yuendumu settlement camp where the lifestyle and diet was westernised, slowing the rate of dental wear.

Similar studies carried out in North America investigating wear patterns in hunter-gatherers' dentition and correlating this with age and sex. For example, Tomenchuk and Mayhall (1979), researched tooth wear in a group of Lgloolik Eskimos in the Northwest Canadian territories, recording three dental traits to determine the differences between the sexes: cusp height; the maximum mesio-distal length; and the maximum bucco-lingual width. The results indicated a strong correlation between tooth wear and chronological age of the individual. However, there was also evidence of intra-sex variability, where the females wore their molar teeth 30% more than males due to specific activities (Tomenchuk and Mayhall, 1979).

Rates of tooth wear in the archaic period (hunter-gatherers), were investigated by Sciulli (1997), who stated that hunter-gatherers showed a high rate of occlusal wear and had low frequency of pathology. This study also looked at the Woodland (transitional) and Mississippian (agriculturalist) periods. The Ohio River Valley Native Americans — from the Late Archaic to Early Woodland periods — demonstrated a constant absence of dental pathologies and high rates of wear, and it was thought that the subsistence patterns and lack of dietary carbohydrates were the causes of the low level of caries and high wear rate (Molleson et al., 1993, Molnar, 1971a, 1972, Molnar and Molnar, 1985, Sciulli, 1997, Smith, 1991, Smith, 1981, 1982, Smith, 1972, 1989, Smith and Horwitz, 1998).

Hinton (1981) conducted a similar study of isolated assemblages from different lifestyles in which he compared the anterior/posterior tooth wear. A series of Eskimo and Australian assemblages that represented non-agriculturalists, and Southwest US and Ohio assemblages represented various degrees of food production populations were studied. The results suggested that people who pursued hunter-gathering lifeways routinely exhibited greater wear on the anterior portion of the dental arches than those associated with food-producing economies (Hinton, 1981).

Several conclusions can be drawn from the North American studies:

- females seem to have greater dental occlusal wear
- there was heavier approximal surface wear and occlusal surface wear in the hunter-gatherer collections
- attrition wear was heavier in the anterior teeth than the posterior teeth
- there were lower rates of pathologies in the hunter-gatherer collections.

Lastly, van Reenen (1992) undertook a study that mirrored the Australian studies (above), focusing on the San Bushman of Southern Africa. His study investigated three groups of individuals from different populations: one comprised nomadic hunter-gatherers, one began life as nomadic hunter-gatherers, and then later settled on farms, and one was from Angola and subsisted almost entirely on westernised diets. It was found by van Reenen, the group that subsisted primarily from hunting-gathering had heavily worn dentition compared to the group from Angola, whose dentition had relatively little occlusal surface wear.

The dental studies reviewed here show that hunter-gatherers wear their teeth differently from agriculturists. The Australian studies used populations that started out as hunter-gatherers and moved to a settlement camp. In the camp the diets and lifestyles became westernised and the tooth wear reduced. The same can be said for the San Bushman of southern Africa. All three regional studies drew similar conclusions. The hunter-gatherers had greater occlusal wear, more approximal wear, and more wear on the anterior teeth than the posterior.

In conclusion, teeth can be a vital element in archaeological studies. It has been shown that teeth:

- survive well in the archaeological record
- can indicate age-at-death estimation and nutritional stresses throughout life
- can be used to identify differences between lifeways based on subsistence behaviour



## Chapter 4 — Framework and Objectives

This chapter summarises the two different studies that constitute the framework of this research. This is followed by the hypothesis and objectives of the current project. The two main goals of this chapter are to:

- explain how the framework for this study was formed
- propose the project hypothesis.

### 4.1 Previous research hypotheses

From Dental Literature Review chapter 3, it is apparent that the studies by Smith (1984) and Hinton (1982) have particular influence upon the development of the current project. These studies are therefore, summarised below.

#### **Smith 1984**

Two elements of the research by Smith (1984) have special relevance to this project. She used collections of modern and prehistoric hunter-gatherers and agriculturalists to explore differences in patterns of tooth wear between these groups, and how these patterns relate to major differences in subsistence and food preparation. She also developed consistent and replicable methods for identifying patterns of dentine exposure, and for recording occlusal wear plane angles. These were combined into an analytical paradigm by correlating occlusal surface wear with the occlusal wear plane angle of the lower right first molar. The central hypothesis behind her work was as follows:

...hunter-gatherer groups would have flatter molar wear due to the mastication of tough and fibrous foods whereas the agriculturists would develop oblique molar wear due to an increase in the proportion of ground and prepared food in the diet (1984 pg. 39).

#### **Hinton 1982**

Rather than examining occlusal attrition, Hinton (1982) studied the development of the interproximal (or approximal) attrition wear, which is caused by the rubbing movement of the teeth during mastication. In order to systematise observations, Hinton correlated the breadth of the P2-M1 and M1-M2 approximal wear facets to the degree of occlusal attrition wear. Hinton's basic premise was as follows:

Because of its functional aetiology, the rate and amount of interproximal wear should be directly related to the magnitude and frequency of forces applied during mastication . . . (Hinton, 1982 pg 104).

The implications for the present project are clear. If the assumption of more resistant foods and increased attrition rates in hunter gatherers is correct ‘. . . the magnitude and frequency of forces applied during mastication’ would lead to increased development of the approximal facets, and this attritional process could also be used to distinguish foragers from agriculturalists in the archaeological record.

#### **4.2 Problems with previous research**

While appropriate for addressing each project’s intended aims, the methods used in the studies discussed above require modification if they are to be used to accurately clarify ancient economic lifeway.

- The Smith study used an eight-ranked ordinal scale to record occlusal attrition wear. However, ordinal recording systems do not allow for intermediate stages, and while this would be acceptable for general observations (i.e. ageing or sex estimates), it is impossible to measure occlusal – or, indeed, approximal – dentine exposure accurately (which can be a very irregular process), without use of a continuous scale.
- In both the Smith and Hinton studies, ordinal stages were compared with to interval measurements. Hinton related approximal facet length (interval) to occlusal attrition wear (ordinal), and Smith related occlusal angle wear plane (interval) to occlusal attrition wear (ordinal). While this does not necessarily invalidate their results, the fact that the data types are dissimilar may lead to complications if the system were replicated and the results treated statistically.
- Hinton and Smith both represented their data by the arithmetic mean, which is only a summary of the data (Field, 2000) and does not take its variability into account. The mean is greatly affected by asymmetry of distributions, and very little is known about the distribution of tooth wear scores or measurements. As this area of research addresses a vast array of societies with almost infinite interpersonal and dietary variability, this method severely weakens the validity of Hinton and Smith’s studies.
- Linked to the previous point, differences in occlusal surface wear patterns were compared between pre-defined groups of foragers, mixed economy groups and agriculturalists, but not within each group. This is a major omission, as the full range of variation in wear patterns between similar assemblages in each group category is equally – if not more – important than the mean values.

### 4.3 Hypotheses for this project

Based on a survey of the published evidence concerning dental wear and dietary proclivity, the following hypotheses were generated.

Relative to agriculturalists, all non-agriculturalists have:

- a high occlusal attrition rate, with reference to independent age-at-death estimates (based on the pubic symphysis or the auricular surface)
- a strong gradient of occlusal attrition, with the lowest rates in more posterior teeth (second premolar to third molar) and the highest rates in the anterior teeth (first incisor to first premolar)
- more approximal wear for any given occlusal wear stage
- a smaller change in the molar wear plane angle, per stage of occlusal attrition.

To overcome the shortcomings of previous studies (as listed above), the four different parts of the hypothesis will be tested by:

1. taking into account the variability of dental attrition, within as well as between assemblages by:
  - a. comparing assemblages representing several different forms of hunting, gathering and/or fishing subsistence, that are usually grouped together into the all-encompassing title of 'non-agriculturalists'.
  - b. comparing assemblages representing different forms of agriculture
  - c. carrying out comparisons with assemblages representing groups that are considered transitional (including hunting, gathering, and/or fishing as important elements, as well as agriculture)
2. using interval scales to measure occlusal wear, thus allowing for values that would have been considered 'intermediate' (and therefore immeasurable) by Smith's system. This will be supplemented by providing a more appropriate system for comparing occlusal wear to the interval measurements of approximal wear and occlusal wear plane angle.

As an additional control on research quality, it was decided to use assemblages not analysed by Smith and Hinton.

#### **4.4 Summary**

Previous research hypotheses have been examined in order to determine how this study might improve the interpretation of dental wear patterns in archaeological assemblages. The approaches used by each of the two most important and relevant works were assessed and adapted according to the current project's stated purpose. The current project aimed to further develop these ideas, and to exploit recent developments in software to more accurately score occlusal wear plane angles, approximal facet morphology and dentine exposure.

## Chapter 5 – Review of Archaeology and Materials

This chapter reviews the archaeological context of the materials used in this project. The collections sampled were from the Harvard University Peabody Museum of Archaeology and Ethnology, the Smithsonian Institution Natural History Museum, the University of Kentucky Webb Museum of Archaeology and Anthropology, and the Natural History Museum (London). The materials are evaluated by institution, taking into account all contextual and background information. The composition of the collections used in the present study is presented in tabular form at the end of this chapter. The goals of this chapter are to:

- give an introduction to the archaeological periods from the assemblages
- present the archaeological background of each of the assemblages
- present the composition of the collections.

There are various hunter-gatherer theories in archaeology (Bender, 1978, Bird-David, 1991, Hawkes, 2001, Kelly, 1992, 1995, Lee and De Vore, 1968, Lieberman, 1993, Stanford and Bunn, 2001, Taylor, 1977, Testart, 1982). However this is not the place to debate what types of hunter-gatherers were involved in this study, nor to debate how the transition from a hunting-gathering lifeway to a more agricultural lifeway took place. The analysis of dental wear in the current project is based upon three distinct economic groups which need to be accurately defined. The three groups used in this study are defined as; *Non-agriculturalists* which refers to groups based upon non-domesticated resources, and subsisted on some combination of gathering, collecting, hunting, fishing, trapping or scavenging (Panter-Brick *et al.*, 2001). The *transitional group* is defined as populations that hunted, gathered and fished for food, but includes a certain element of agricultural practice. *Agriculturalists* (or food-producing groups) are defined as those groups with a primary dependence upon domesticated plants and animals (Harris and Hillman, 1989).

These North American and Levantine assemblages were chosen because both regions show strong evidence of the transition from a non-agricultural society to a food-processing society. Evidence for this was found not only through the archaeology (botany, zoology, lithics and pottery), but also from stable isotopes (Lambert and Grupe, 1993, Lambert and Walker, 1991, Garrard, 1998, 1999, Garrard *et al.*, 1985, Garrard *et al.*, 1996, Griffen, 1946, Horwitz *et al.*, 1999, Price and Gebauer, 1995, Rose *et al.*, 1991, Scarry, 1993a, Titterton, 1935) which support the transition from a non-agricultural

society to an agricultural or food producing lifeway. In addition, there were also ample skeletal collections from these various institutions (see above) that were readily available for studying.

## **5.1 Review of archaeological background**

The North American non-agricultural sample consisted of the Carlston Annis, Chiggerville, Indian Knoll and the Santa Barbara Channel Island collections. The Levantine sample included specimens from El Wad and Kebara. The transitional group was represented by a single collection from the Calhoun County, Knight Mounds, Illinois. The North American agriculturalists were from the Shannon, Hawikuh, and Florida Canaveral Peninsula sites. The site of Abu Hureyra represented the Levantine agriculturalists. The basic archaeological information – including chronology, map of North American and Levantine sites (figures 5.1 and 5.2) and population history – is presented below.

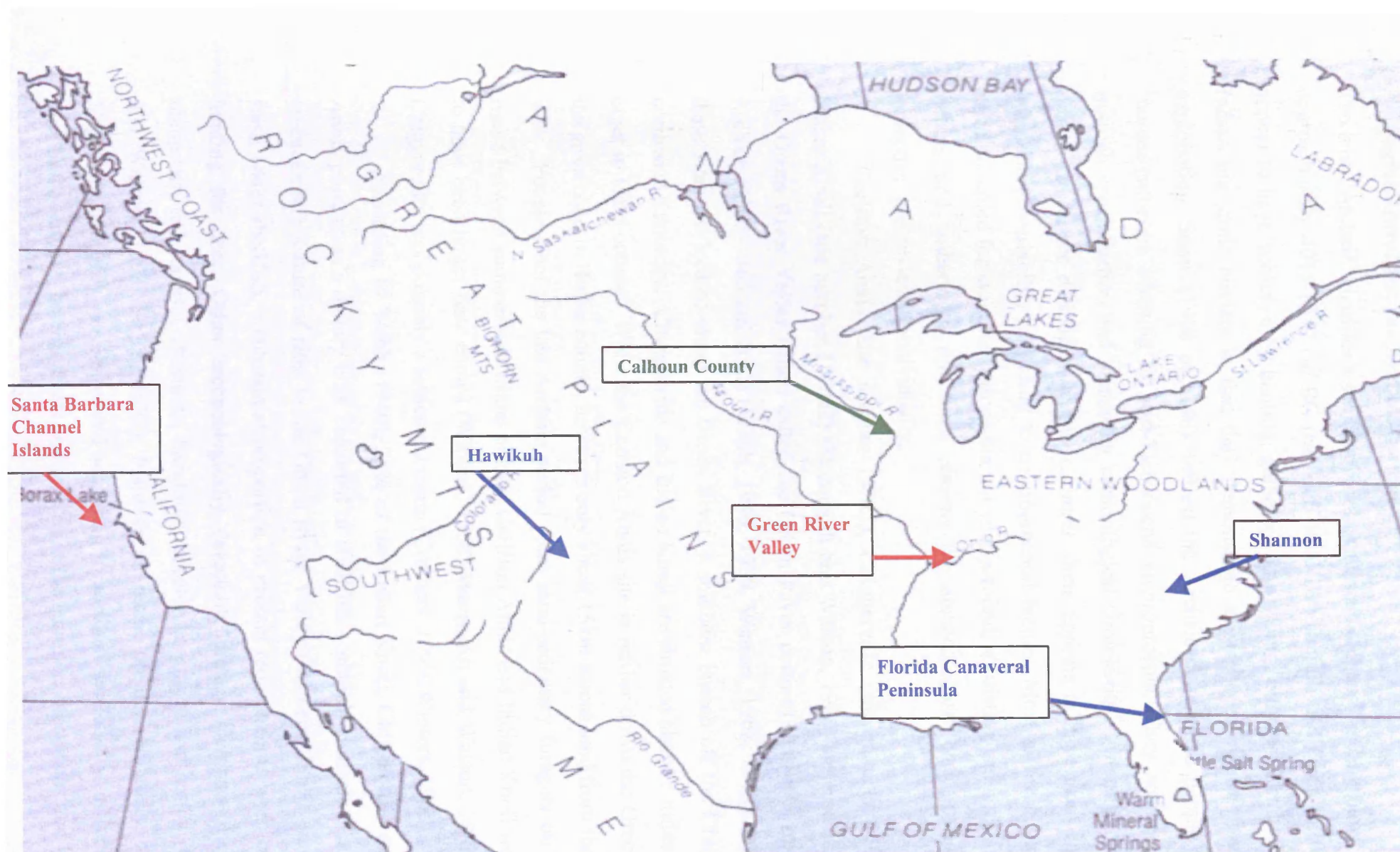


Figure 5.1: Map of the North American assemblages. Assemblage in red are non-agriculturalists, green=transitionals and blue=agriculturalists. The Green River Valley includes the Indian Knoll, Carlston Annis and Chiggerville.

## ***North American archaeology and collections***

### **Non-agriculturalists: the Archaic period**

The term 'Archaic' signifies a series of North American archaeological groups – dating to approximately 4035-1050 *cal* BC (ca 6000-3000 BP) (Sciulli and Oberly, 2002) – that appear to have subsisted by hunting, gathering and fishing, but are distinct from Paleo-Indian big game hunters in that they demonstrate a wide spectrum of food resource exploitation. Snow (1996 pp. 146) defined the Archaic cultures as people who were 'hunter-gatherers adapting to post-Pleistocene environments. They accomplished this through specialisation and increasing technological complexity'. Although the Archaic groups can all be defined as non-agricultural, there appears to have been considerable behavioural variability according to environmental factors. Most of the habitation sites were occupied for multiple seasons but not year-a-round, subsisting primarily by hunting, fishing and gathering. For these reasons the archaeological background for each collection was reviewed individually.

Carlston Annis (site number 15Bt5), Chiggerville (site number 15OH1), and Indian Knoll (site number 15OH2) (Marquardt and Watson, 1983) are assemblages from the Green River Valley (often called the Green River culture) that date from the late Archaic (3385  $\pm$  365 *cal* B.C.) (Webb, 1946, 1950, Winters, 1968, 1974). All three of these sites are located along the Green River, a southern branch off the Ohio River, in northwest Kentucky. Chiggerville and Indian Knoll are situated about 3 miles from each other in Ohio county. While the Carlston Annis site is further down the Green River on the great bend in Butler county, however only about 15km across land from the other two sites. People from the late Archaic period were semi-sedentary foragers on a seasonal round between summer and winter camps. Carlston Annis and Indian Knoll were thought to have been larger base camps (Winters, 1968, Marquardt and Watson, 1983), whereas Chiggerville was possibly a settlement camp (Crothers, 1999, Winters, 1968).

According to Webb (1940), 25% of the Indian Knoll, Chiggerville and Carlston Annis population's dietary bulk consisted of shellfish – notably mussels – and this is a characteristic feature of sites in the Green River Valley (Winters, 1969). In addition to fresh water shellfish, a substantial proportion of protein requirements were met through hunting for deer. Other archaeologically detectable dietary elements include small mammals, fish, acorns, chestnuts, hazelnuts, beechnuts, grapes and honey (Champman and Watson, 1993, Fagan, 1995). Plant foods made up the remainder of the diet. Vegetable resources were harvested according to seasonal availability, including oil-rich nuts in the autumn, berries, fruits and grasses in the summer, and greens and bulbs in the



spring (Morey *et al.*, 2002). These foods were most likely prepared with hammer stones, stone mortars and pestles (Jennings, 1989). One thousand four hundred and thirty eight pestles were recovered from Indian Knoll, 276 from Carlston Annis, and 123 from Chiggerville. These numbers may not reflect the actual amount of such artefacts originally used at each site – and therefore the relative importance of ground plant food – as only unbroken artefacts were collected and recorded (Webb, 1974, Winters, 1968). Substantial quantities of hickory nut shells – which were found around the hearths – attest to the practice of crushing and boiling the nuts in order to make hickory butter (Winters in Webb, 1974). These populations can therefore be described as having had a harvesting, hunting and gathering economy, based upon staples of deer, mussels and nuts (Winters in Webb, 1974).

People from the Green River Culture were rich in many natural resources, (see above) and were fairly successful semi-sedentary foragers and hunters. Tool kits contained artefacts such as ground stone tools (atlatl weights, grooved axes, and mauls, hammer-stones, pestles, milling stones and nut-stones) bone tools (fish hooks, bodkins, and animal teeth used for engraving tools) and chipped stone tools (points, side and corner notched, knives and drills) (Crothers, 1999, Morey *et al.*, 2002, Webb, 1974). Each of these artefacts suggests they were used for processing food (milling stones, nut-stones, pestles) as well as hunting big game (atlatls and spears) and fishing (bone fish hooks).

The second assemblage of North American non-agriculturalists was recovered from cemeteries in the Santa Barbara Channel Islands. The early Archaic period in California was characterised by notable cultural and economic variability, as evidenced by archaeological remains as well as palaeopathological and isotopic analyses (Lambert and Walker, 1991). Despite the lack of a land bridge to the mainland – and the relatively small number/size of islands – well over 1000 sites have been recorded in the Santa Barbara group (Erlandson, 1994).

The Santa Barbara Channel Islands are a chain of four islands: San Miguel, Santa Rosa, Santa Cruz and the Anacapa Islands. These Southern Californian islands, which are situated about 40 km from the Santa Barbara coastline (Erlandson, 1991), are an ideal environment for investigating the physical anthropology of Californian Native Americans, as the people from Santa Barbara did not subscribe to the cremation practices of their mainland contemporaries (Walker and Hollimon, 1989, Walker *et al.*, 1991). Features associated with non-agriculturalist complexity were firmly in place at the time of European contact, although it is unclear as to when people began to live in permanent

settlements in the area. Features associated with social complexity include large and numerous residential bases, ascribed status, intensive use of marine resources, large, dense populations, permanent villages, inter-village exchange and technical specialisation (Lambert and Walker, 1991). As indicated by the paleopathological and isotopic data found from the skeletal remains of the inhabitants of the Santa Barbara Channel Islands, there was a shift from hunting and gathering to a lifeway based mostly on intensive marine resource exploitation. This change in behavioural practices was seen in a decrease of carious lesions in the dentition (from a diet mostly marine food) and isotopic concentrations in bone that suggests increasing dependence on protein derived from marine animals (Walker and Thornton, 2002).

The remains used in this study were collected from the Santa Cruz Island, which is the largest of the northern Channel Islands and contains nearly 1000 sites (Erlandson, 1994). During the early period, occupants relied heavily on shellfish (90%), supplemented by fish (5.4%), sea mammals (3.8%) and other more minor elements (Erlandson, 1991, 1994). There is also possible evidence of the inhabitants hunting dolphins for a source of protein and fat (Porcasi and Fujita, 2000). As is common on oceanic islands, the terrestrial fauna of the Santa Barbara Channel Islands are somewhat impoverished. Marine resources therefore provided nearly 100% of the animal protein consumed by early period groups. The islands are ideally placed in this regard. The marine environment of the island is heavily influenced by cold-water currents moving southward along the coast, pulling nutrients from deep-water layers up to the ocean surface. These nutrients support plankton, which attract large schools of fish, which in turn attract large fish, marine mammals, and, apparently, humans (Walker, 1996). Bone gorges and barb elements from compound fishhooks indicate a marked emphasis on ancient marine fishing.

Indigenous or imported land plants were probably a significant carbohydrate and caloric resource. However, the low protein content of available plant foods would seem to suggest that such materials were a relatively marginal resource, and that shellfish and other marine resources played a more dominant role in the livelihood of the inhabitants (Erlandson, 1991, 1994, Glassow et al., 1988, Lambert and Walker, 1991, Walker and Erlandson, 1986, Walker and Thornton, 2002). Isotopic analysis of human bone from the island indicates that the islanders had diets similar to fish-eating marine mammals such as seals and sea lions, substantiating the archaeological evidence of a heavy reliance upon marine animals and fish (Lambert and Walker, 1991). The only native terrestrial

mammals to survive on the northern Santa Barbara Channel Islands were small species of foxes and skunks, and three species of rodents (Walker, 1980).

From the evidence presented here, it is clear that the inhabitants of the Santa Barbara Channel Islands were primarily fishers and marginal gatherers of plants foods. The Channel Island sites contain vast quantities of shellfish, sea mammals and fish remains while milling stones were very rare. There is therefore little evidence to dispute that the islanders placed little emphasis on harvesting plant foods (Walker and Erlandson, 1986)

### **Transitional group: the Late Woodland period**

Following the Archaic period came the Woodland period, which is thus defined by Griffen *et al.* (1970):

The term Woodland is used in a very loose sense to refer to the data from prehistoric sites in the Eastern United States from about 1000 BC to the historic period by a large number of diverse societies that made pottery that was coiled, often cord marked on the interior surface or otherwise paddled to complete the outer surface finish . . . . The late Woodland refers to the post-Hopewellian Woodland societies that lasted up to the early historic period, particularly in the north eastern United States and Canada (1970 pg 1).

The transitional sample was collected from the Knight Mounds of Calhoun County in the Lower Illinois River Valley (southern Illinois, on the Illinois river just before it runs into the Mississippi River) and was dated to the Pike and Fox Creek phases of the Late Woodland period (200 BC–AD 500) (Griffen *et al.*, 1970, Taylor, 1977). Like most Late Woodland sites in the Lower Illinois River Valley, the site is located at the base of the bluffs (Asch *et al.*, 1979). Agriculture's potential role in the cultural development of Middle and Late Woodland populations is still a subject of controversy (Asch *et al.*, 1979), although it is certainly true that agricultural practices are not likely to have played a major part in Late Woodland economy. The evidence for this however, is somewhat ambiguous. While excavations of some Middle Illinois Woodland sites showed minor presence of maize before AD 700–800 (Asch *et al.*, 1979), the Calhoun County occupants appear to have relied upon several species of wild plants (as well as animals) on a seasonal round, including knotweed/goosefoot (fall maturing), maygrass/barley (spring maturing), and marshelder/sunflower (Smith, 1992). Johannessen (1984) believed these seeds signified the development of a lifeway increasingly reliant upon storable dietary staples. However, while this is probably true, the relevant fact for the present study is that wild and domestic plants were being exploited, as well as standard forager staples. This

would therefore suggest that Middle/Late Woodland period populations had developed a hybrid food-producing and foraging system – probably as a response to climatic unpredictability – that maximised turnover (and possibly storage) of seasonally restricted plant foods (Fritz, 1993). For these reasons, this collection is defined as ‘transitional’ in that they never subsisted totally on farming or upon foraging, preferring to exploit the advantages of each economic option.

Titterington (1935) suggested that the population from the Calhoun County were foragers, with a minor element of crop production that was not in itself sufficient to provide full subsistence. The site is certainly well positioned to facilitate a wide spectrum of economic potentialities. The landscape consists of sloughs, lakes, rivers and marshes in broad floodplains, with the Knight Mounds located on the bluffs east above the flood plain of the Illinois River, to the north of Fox Creek (Griffen *et al.*, 1970).

The artefacts from Calhoun County sites reflect this wide economic adaptation, including corner-notched arrowheads, long expanding-stemmed arrowheads, short-stemmed arrowheads, that may have been used for hunting diverse wild game while hammer-stones, mortars and pestles were used for processing various cultivated and gathered foodstuffs (Titterington, 1943). It was suggested that foods were probably prepared with stone tools, then further processed by means of boiling in the grit-tempered ceramic vessels that have also been recovered from the site (Griffen, 1946, Kehoe, 1992, Titterington, 1935).

### **Agriculturalists: the Mississippian period and Ancestral Puebloan culture**

Southeast US agricultural collections were from Florida, the Florida Canaveral Peninsula and the Shannon site, in Virginia (Mississippian period). Southwest US samples were collected from an Anasazi or Ancestral Puebloan site. In basic terms, the term ‘Mississippian’ describes prehistoric populations living in the eastern deciduous woodlands from AD 800–1500. It has been proposed that the Mississippian period be further defined as ‘a culture of adaptation to a specific habitat situation, and as a particular level of sociocultural integration’, rather than using the traditional material culture definition based on the presence of rectangular, truncated, substructure pyramidal mounds and shell-tempered pottery (Smith, 1978). The general nature of Mississippian subsistence strategies has been known for some time, from both historical and archaeological evidence. Early Spanish explorers told of passing through territories where fields were planted with maize, beans, and squash (Smith 1968 in Scarry, 1993b), while evidence from numerous sites have since reinforced the belief that Mississippian period was based on cereal and pulse agriculture (Scarry, 1993a, 1993b). Mississippian

populations also utilised a limited number of wild plants and animals representing seasonally abundant energy resources, including various fish species, migratory waterfowl, nuts, fruits, berries and seed-bearing pioneer plants. Plant cultivation was centred on maize, beans and squash, as well as more minor crop elements such as marsh elder, sunflower and gourd (Smith, 1978).

Human remains from the Mississippian period showed evidence of marked physiological stress, including Harris lines on the long bones and dental enamel hypoplasia (Buikstra and et.al, 1986). This is probably related to contemporary population increases, which in turn is associated with sedentism, increasing population density and – resultantly – lower levels of hygiene (Larsen, 1997). This expansion in population has also been linked with earlier weaning and shorter birth intervals associated with the availability of soft palatable foods (Smith, 1992); the weaning foods in question are likely to have been boiled cultigens (Smith, 1992).

The Mississippian culture in central eastern Florida has been dubbed ‘the St Johns Culture’, and is dated from c.AD 500–1565 (Milanich and Fairbanks, 1980). The Florida Canaveral Peninsula collection – which was used in the present study – dates to the later part of this period (Stirling, 1934, 1935). Maize agriculture, which was established in northern Florida at about AD 750, was the substance mainstay for this group, leading to the proliferation of farmstead-like settlements (Kehoe, 2002). It should be noted, however, that there was considerable lifeway diversity in accordance with site placement, with increased reliance upon gathered resources at coastal sites. At the Florida Canaveral Peninsula site, the coastal shell mounds, oyster shells comprised 60–90% of the mounds and indicated extensive occupation during the St Johns IIA and IIB cultures (Milanich and Fairbanks, 1980). Animals consumed at this coastal site included deer, turkey, raccoons, opossum, rabbits, wildcats, and various species of fish (especially mullet, shark and redfish). Birds – including loons, gannets, ducks, turkey vultures, herring gulls, black-back gulls and brown pelicans – were also exploited (Reitz, 2004). Evidence for agricultural practices at any of the coastal sites is limited, although corncob-marked pottery from the St Johns area does imply at least a minor presence of maize horticulture. Other carbohydrate resources included maygrass, goosefoot and nuts (Milanich and Fairbanks, 1980).

Little is known of the toolkit that was used at this site, however, from the faunal remains (fish and birds) and the close proximity to the sea, it is most likely that the inhabitants were primarily fishers with little emphasis on gathering food stuff, similar to the Santa Barbara Channel Island sites. With the evidence corncob marked pottery found

within the area and isotopic analysis would imply some agricultural practices, however they might not have been the major focus of the inhabitants (Milanich and Fairbanks, 1980, Worth, 2001).

The Shannon assemblage was recovered from the Ronake River area (Montgomery County, Virginia), located about 350 miles from the Atlantic coast (Benthall, 1969) and dated from AD 1550–1600. The archaeological materials include shell-, limestone- and grit-tempered wares, and a variety of projectile points in the remains of a riverine palisade village. The people of Shannon are believed to have been members of a simple farming community with a lifeway based upon corn and bean agriculture (Benthall, 1969). The foods were in all likelihood cultivated on garden plots in the low grounds near the village; where domesticated corn, bean and probably squash were grown. These domesticated crops were supplemented with nuts berries and roots that were most likely gathered from the near by mountains and forests (Benthall, 1969), while game was hunted in the surrounding area. From the faunal remains it is suggested that every type of animal in the area served as a source of food (mostly Virginia White Tail Deer, and Elk). Fish were also utilized for food, as indicated by the presence of fishhooks (Benthall, 1969). Several hearths, storage and refuge pits were found with ceramics and projectile points near which could suggest that cooking within the wares (limestone, shell or grit tempered) were feasibly involved with the food processing.

Although the late dates of this site suggest that the village may have been inhabited during the Spanish occupation, there however was no evidence of Spanish trade goods or Spanish remains to support any occupation at the Shannon site.

The last North American collection to be assessed was recovered from the Hawikuh site, located in the high plains desert of New Mexico. The archaeological data for this southwest area – which is the homeland of the Ancestral Pueblo culture – attests to a 2000-year history of economic experimentation, cultural innovation and population fluctuation (Kintigh, 2000). The Hawikuh site is thought to have been occupied during the late Anasazi to possibly early Zuni (approximately 1300 AD) (Kintigh, 2000, 2003). Agriculture became a mainstay of the North American southwest sometime between 200 AD and 1000 AD (Minnis, 1992, 2000). Therefore an agricultural way of life was already strongly established when the Hawikuh people inhabited the area. The subsistence and lifeway of the Hawikuh inhabitants were primarily based upon dry-farmed crops (flood water irrigation) – notably maize, squash, beans and cotton (Minnis, 1992, 2000), supplemented by gathered foods and hunted game (Smith *et al.*, 1966). During the last quarter of the 13<sup>th</sup> century, the Anasazi economy began to suffer from

prolonged winters and severe droughts (Kintigh, 2000, Smith et al., 1966), prompting a move to more fertile lowland areas. The Hawikuh people are thought to have merged into what is known today as the Zuni culture (Kintigh, 2003).

Some of the more common artefact found within the Hawikuh were several styles of mortars and pestles with various types of handstones. Snares, digging sticks, bows and arrows, various chipped stone tools and netting were used for hunting and food gathering. Several different styles of pottery were also found within the pit style houses (Cordell, 1997, 1999, Lipe, 1983).

### **Levantine archaeology: background and collections**

The areas from which the Levantine collections are derived are located on the map below in figure 5.2.



Figure 5.2: Map of Levantine collections. El Wad and Kebara are non-agriculturalists and specimens from the Abu Hureyra are agricultural.



In addition to the North American collections, the author also analysed small collections from the Levantine Late Natufian (Epipaleolithic) and Pre-pottery Neolithic B periods. These periods play a pivotal role in human economic development, testifying as they do to a series of social and economic transformations from partially mobile complex hunter-gatherer groups to fully sedentary agricultural societies. It is therefore appropriate to fully discuss the behaviour background to each of these groups.

The Epipaleolithic spans the period from 20,000–10,250 *cal.* BP (Byrd, 1994), and was characterised by climatic changes that had a major impact on contemporary human populations and the landscape in which they lived. The climate saw marked oscillations in temperature and resultant ecology, starting with the Late Glacial Maximum at 19,000 *cal.* BP, followed by the return to warmer conditions in the terminal Pleistocene. The most dramatic change was the subsequent ‘snap’ returns to the cold conditions in the Younger Dryas 13,000 *cal.* BP, and the shift to the warmer, wetter climate of the Early Holocene at 11,500 *cal.* BP. Many researchers have attributed the major social changes that took place at this time to loss of foraging potential in the Northern Levant (Bar-Yosef, 1980, Belfer-Cohen, 1991, Goring-Morris, 1995). While it is also possible that the changes occurred due to burgeoning social complexity (a response to increasing population size in this period), the fact that Epipaleolithic groups were already gathering and processing substantial quantities of wild cereals would seem to predispose them to agricultural practices in times of economic hardship.

The late Epipaleolithic period was the period in which the hunter-gatherers possibly started cultivation, and is often considered to be synonymous with the Natufian culture (Bar-Yosef, 1980) bracketed between 14,700 and 12,000 *cal.* BP (12,650–10,450 *uncal.* BP) (Wright, 2000). This culture was initially based on a series of sites excavated in the 1930s in Palestine (Garrod and Bate, 1937), and appears to have been a group of complex non-agricultural societies that demonstrated a wide range of local adaptations along a general socio-economic theme (Goring-Morris, 1995). There is continuous debate as to whether Natufian groups were mobile or sedentary (Valla, 1995), although the discovery of ‘base camps’ and ‘exploratory camps’ seems to suggest temporospatial flux in mobility patterns and, therefore, social affinity.

Originally, the presence of flint blades with sickle gloss led Dorothy Garrod to suggest that the Natufians were the first farmers in the Levant (Valla, 1995). However, certain features suggest an increased reliance on foraging for wild cereals (Garrard, 1999, Smith, 1995), which grew in profusion throughout the region. The limited palaeobotanical evidence available indicates that pulses, cereals, almonds, acorns and other fruits were

gathered, while mortars, pestles, sickles, querns, grinding slabs and storage pits might imply that the Natufians were harvesting and processing wild cereals and legumes (Bar-Yosef, 1998, Henry, 1989). Wright (2000) suggested that mortars and pestles may have implied emphasis on nuts, while grinding slabs and hammer stones indicated the exploitation of smaller seeds. Further evidence of this plant-rich diet has been provided by physical anthropology. Smith (1991) proposed that the Natufians had a very abrasive diet, incorporating large quantities of ground cereals (with mineral inclusions from mortars etc.), based on the generally poor condition of the dentition. Linked to this severe attrition, 10% of the adults showed exposure of the dental pulp, abscesses in the periodontal bone and tooth loss (Smith, 1991). The remains of wild game (gazelle, fox, and fallow deer) indicate that the Natufians supplemented this carbohydrate-rich diet by hunting (Bar-Yosef, 1998, Sillen and Lee-Thorp, 1991, Valla, 1995).

One of the Natufian collections used was from the site of El-Wad, on the southern side of Nahal Me'arot escarpment in Northern Israel. This Late Natufian site dates to about 13,150–12,000 *cal.* BP (11,250–10,250 *uncal.* BP according to Belfer-Cohen (Belfer-Cohen, 1988 in, Weinstein-Evron, 1998), but is also notable for having a complete period sequence (Mousterian, Upper Palaeolithic and Early/Late Natufian layers (Weinstein-Evron, 1998). The Natufian finds were mostly on the terrace of the cave (Weinstein-Evron, 1998), with close to 100 burials accompanied by a rich material culture.

South of the El Wad site, the nearby Natufian site of Kebara was also assessed. The site, which was discovered in the 1930s, contained several Natufian skeletons in a central burial ground, a few cremated fragmentary skeletons, and a rich lithic and animal bone industry (Bar-Yosef, 1995). The Natufian layer dates to 13,500–12,750 *cal.* BP (11,650–10,650 *uncal.* BP dates from Stuiver and Reimer, 1993, Weinstein-Evron, 1998), and overlies Upper Palaeolithic and Mousterian layers (Bar-Yosef, 1995). The artefacts recovered include bone tools, pendants, ornaments and decorated sickle hafts, mortars and pestles, stone tools, shaft straighteners and whetstones (Turville-Petre, 1932). A pit with several damaged Natufian skeletons was found close to the entrance of the cave (Bar-Yosef and Vandermeersch, 1991), and only these remains were studied for the present project.

The transition from a mostly hunter-gatherer (Natufian) to a hunter-farmer (Pre-Pottery Neolithic A (PPNA) society took place in a 500-year period from 12,000–11,500 *cal.* BP (Bar-Yosef and Belfer-Cohen, 1992). The PPNA hunter-farmers represented a shift in the economic base of societies inhabiting the arid zones. Instead of the Natufian

exploitation of wild cereals, legumes, seeds and fruits, these groups began a more systematic cultivation of cereals and legumes (Bar-Yosef, 1992b). In addition to the few established villages (e.g. Mallaha and Abu Hureyra), this period saw a move from cave/cave terrace habitation to established villages with evidence of agriculture, along with polished stone axes, pottery, and an array of domesticated cereals and animals (Bar-Yosef, 1992a).

Farming communities were well established by the Pre-Pottery Neolithic B period (PPNB), which is dated to 10,950–8,900 *cal.* BP (or 9,600–8,000 *uncal.* BP) (Bar-Yosef, 1980). In addition to agricultural (cereal and legume) food production, the lifeways of this period were characterised by the consumption of wild game that was either hunted or obtained from other hunter-gatherer groups. Sheep, goats and pigs were domesticated in western Asia during this period, and subsequently spread throughout the Levant and beyond (Horwitz *et al.*, 1999). Wild fruit and other plants were still gathered (Bar-Yosef, 1992b). The establishment of farming communities during the PPNB led to profound social changes in these societies, particularly in gender roles, as the extra work load during the sowing season, coupled with the effects of sedentism and population growth, meant that large-scale long-distance foraging (probably carried out by males) became a necessity. This marked the departure from the small-scale, locally based subsistence strategies that had characterised the Natufian economy. During the Neolithic, food was both harder and coarser, gazelle meat, continued to be eaten and cereals were a mainstay within the diet (Smith, 1972, 1989, 1991, Smith and Horwitz, 1998). By the end of the PPNB however, domesticated sheep and goat became a mainstay in the diet. Preparation of grains, dehusking and grinding was a daily activity. Once seeds were dehusked they would not keep; therefore dehusking small grains in a mortar with a pestle and many subsequent grinding of grain in the saddle quern would have taken hours each day (Hillman, 1975, Molleson, 2000). The introductions of cultivation would have introduced the additional labour of preparing the soil, planting the seeds, harvesting the grains and pluses and organizing the storage (Molleson, 2000).

Abu Hureyra was the only Levantine agricultural collection to be assessed for the purposes of the present project. Abu Hureyra was located on the banks of the Euphrates Valley, a fast-flowing river that provided rich marshland environments for riparian plants and animals (Moore *et al.*, 2000). The remains from this site indicate a transition from hunter-gatherer to agriculturalist economy. It was suggested by Molleson (2000), that Abu Hureyra was at the origins of agriculture and herding, however, there is evidence of labour, craftsmanship and forms of family structure in the remains. The best indications

of diet from Abu Hureyra were the micra and macrowear condition of the jaws and teeth. According to Smith (1972) evidence of change may be related to the adoption of cultivated cereal crops and possibility the switch from reliance on gazelle meat to products of domesticated sheep and goats (Molleson, 2000). This study used individuals that were thought to have been from the Period 2 phase of occupation at Abu Hureyra. The dates of this occupation are 8,300-7,300 BP (Moore, 2000).

The collections used for this study were from Period 2, which is further divided into Periods 2A and 2B. By the start of 2A people of Abu Hureyra were cultivating at least three domestic wheats and barley. Later in 2B, these crops were joined by chickpeas and field beans (Hillman, 2000). The faunal remains showed that the presence of sheep and goat were the same in both periods, however, the herd sizes were larger in 2B (Legge and Rowley, 2000). By the end of Period 2A and into 2B, there was a large human population growth, larger domestic herds, less diversity in grains and a fuller farming and herding subsistence society. To this end, the PPNB skeletal remains from this site were analysed. It is however unclear which period they came from.

## 5.2 Materials used

Materials were chosen on some basic criteria. The individual had to be an adult, and have at least 6 teeth. It did not matter if the teeth were in the jaw or loose, but they had to be in fairly good condition (complete). With some of the collections, (Hawikuh, Chiggerville, Carlston Annis and Indian Knoll) time was short and only the best-preserved individuals were studied. This however is no reflection on the preservation of the collections, for they were in great condition and well stored. Generally the collections were in fair preservation, (many of the postcranial remains were fragmented or missing), but the cranial remains (mandible/maxilla and teeth) were mostly present. The materials discussed above are summarised by site and period in Table 5.1

COLLECTION	TOTAL INDIVIDUALS	% OF COLLECTION	MALE	FEMALE	UNKNOWN SEX	TOTAL TEETH
El-Wad	60	80%	19	18	23	989
Kebara	10	52%	5	2	3	136
Abu Hureyra	79	77%	12	9	58	760
Santa Barbara Channel Island	85	91%	50	21	14	1152
Calhoun County Knight Mounds	96	75%	55	39	2	2169
Florida Canaveral Peninsula	106	56%	57	44	5	1804
Hawikuh	87	33%	36	49	2	1647
Shannon	61	49%	26	29	6	1259
Carlston Annis	105	27%	51	44	10	1732
Chiggerville	32	48%	21	10	1	587
Indian Knoll	169	20%	81	80	8	3634

Table 5.1: Total number of individuals, percentage used in each collection used, number of known and unknown sexed individuals as well as total teeth used in this project.

### **El-Wad**

D. Garrod excavated El-Wad between 1929 and 1933 (Garrod and Bate, 1937). The materials used were from the Natufian layer (B2 and B1) (Weinstein-Evron, 1998); the Mousterian, upper Palaeolithic and Holocene samples were not assessed. The majority of the remains were in adequate condition, with most of the remains present and intact. Fifteen individuals were not used because they did not have sufficient dentition for the study's criteria, therefore, the El-Wad collection consists of 75 individuals, of which 60 specimens used (19 males, 18 females, 23 unknown,) with a total of 989 teeth (see Table 5.1). These remains are housed at Harvard University in the Peabody Museum of Archaeology and Ethnology, Boston, Massachusetts.

### **Kebara**

F. Turville-Petre first excavated Kebara in 1931, and recovered various human remains in the Early Natufian layer (Bar-Yosef, 1995 , Bar-Yosef and Vandermeersch, 1991). Many of the specimens from the Kebara collection are still packed in mud and have not been cleaned; therefore, several of the dentitions could not be properly studied. The human remains in the mass grave were not used, as individuals in this mixed sample could not be accurately distinguished. The overall preservation of this collection was fairly poor. The specimens chosen for this study were the best preserved of the collection. This study employed all the useable materials from the Kebara collection, comprising of 19 individuals 10 fit the criteria of the study (5 males, 2 females and 3 unknown) with a total of 136 teeth (see Table 5.1). These remains are also housed at Harvard University in the Peabody Museum of Archaeology and Ethnology, Boston, Massachusetts.

### **Abu Hureyra**

Abu Hureyra was discovered by van Loon in 1967 (van Loon, 1968). Abu Hureyra was excavated as a salvage project in the early 1970's (Moore *et al.*, 2000), when the site was threatened by the artificial lake, Lake Assad which now covers it (Hillman *et al.*, 1989). Abu Hureyra was located near the Euphrates River at the edge of the Euphrates Valley (Molleson, 2000). This site yielded remains from the Epipalaeolithic and the early Neolithic periods (Moore *et al.*, 2000). The overall preservation of this collection was fairly poor with most specimens represented by a few bone fragments. Dental remains were most often loose from the jaw and not associated with a mandible or maxilla. The materials scored for this site date to the PPNB period, comprising 102 Neolithic individuals with 79 individuals used (12 males, 9 females, and 58 unknown), with a total sample of 760 teeth (see Table 5.1). These remains are housed at the Natural History Museum of London.

### ***Santa Barbara Channel Island***

Richard Van Valkenburgh, Milton Snow, Eugene Robinson and Nocodemus Villasenor excavated the Santa Barbara Channel Island group in 1932 (personal communication from Dr Kruszynski). This collection was part of a larger assemblage that is kept at the University of California, Santa Barbara. An assemblage from the Santa Cruz Island collection is currently curated at the Natural History Museum of London. Eighty-five individuals (50 males, 21 females and 14 unknown) fit the criteria from the Santa Cruz group (93 in the full collection) with a total of 1152 teeth (see Table 5.1). The preservation of this collection was fairly good, however, the specimens not used was predominately due to extensive enamel cracking/chipping. These remains are housed at the Natural History Museum of London.

Many of the site reports for the Calhoun County, Florida Canaveral Peninsula, Hawikuh and Shannon collections (see below) were absent or incomplete. Included here is as much relevant information as could be gleaned from the available reports.

### ***Calhoun County***

Archaeological interest in the Calhoun County has existed a long time, possibly as early as 1875, when William McAdams was actively collecting and excavating Calhoun County. In 1912 about half of his collection was lost due to a fire and since that time the remainder of his collection was stored and not available for study (Titterington, 1935). At some point, the Calhoun County collection was moved to Washington University in St. Louis. In 1943 the remains from Calhoun County (transitional group) were studied at the St. Louis Department of Sociology, Washington University. The remains were later given to Dr Titterington at the Smithsonian Institution in Washington DC. Actual site reports are thought to have been lost in the fire, therefore little information on the excavation is known about the collection. The materials used were from the Knight Mound group (128 total individual) included 96 individuals (55 males, 39 females and 2 unknown) with 2169 teeth (see Table 5.1). Generally the preservation of Calhoun County was fairly good. The individuals that were not used did not have cranial remains or sufficient number of teeth. These remains are currently curated at the Smithsonian Institution, Natural History Museum (Washington DC).

### ***Florida Canaveral Peninsula***

The Florida Canaveral Peninsula site (agricultural group) was located in Bevard County Florida, and excavated in 1933 and 1934 under the Federal Emergency Relief Archaeological Projects under the direction of Dr George Woodbury, assisted by Erik K.

Reed (Stirling, 1934, Stirling, 1935). Little else is known about the excavation of this site. The analysed samples were from mounds A and D, comprising 186 total individuals from the collection, 106 individuals were used (57 males, 44 females and 5 unknown), with a total of 1804 teeth (see Table 5.1). Like Calhoun County, the overall preservation of this assemblage was fairly good and the individuals that were not used did not have cranial remains or sufficient number of teeth. These remains are currently curated at the Smithsonian Institution, Natural History Museum (Washington DC).

### **Hawikuh**

The Hawikuh collection (agricultural group) was recovered from McKinley County, New Mexico. The Museum of American Indian, Heye Foundation, sponsored the Hendricks-Hodge expedition from 1917–1923 (Kintigh, 2000) and excavated the collection of +250 individuals (Smith *et al.*, 1966). This assemblage is now under special curation due to the strong cultural affiliation it has with extant Native American groups. The Zuni people have agreed to let the Smithsonian Institution house this collection until the direct cultural/biological descendants can be traced and the remains repatriated. This collection was excellently preserved and the author looked at as many as her time at the Smithsonian allowed. The total number of individuals used was 87 out of 259 (36 males, 49 females and 2 unknown) with a total of 1647 teeth (see Table 5.1). These remains are curated at the Smithsonian Institution, Natural History Museum (Washington DC).

### **Shannon**

This collection (agricultural group) was excavated under the supervision of Joseph Benthall in 1966, but little else is known about its archaeological or cultural context. The preservation of the individuals in this collection was fairly poor. Many of the specimens were not used because of the poor reconstruction (which was done before the specimens were in the care of the Smithsonian) of the dentition within the maxilla and mandible, as well as teeth being with the wrong individuals. Only the individuals that had little to no reconstruction to the dentition were used in this study. The number of individuals used was 61 out of the 124 (26 males, 29 females and 6 unknown), yielding a total of 1259 teeth (see Table 5.1). These remains are again curated at the Smithsonian Institution, Natural History Museum (Washington DC).

### **Carlston Annis**

In 1939 the site of Carlston Annis (non-agricultural) was excavated under the direction of Mr Ralph D. Brown and Mr James R. Greenacre (Webb, 1950). Carlston Annis was one of the two largest shell midden sites in Butler County (Webb, 1950). The number of individuals employed from Carlston Annis (390 individuals in the total collection) was

105 (51 males, 44 females and 10 unknown), with a total of 1732 teeth (see Table 5.1). Generally the postcranial remains were in fairly good condition, but about half of the specimens did not have a cranium or sufficient number of dentition. However, the author looked at as many as time allowed at the university. These remains are curated at the University of Kentucky, in Lexington, Kentucky.

### ***Chiggerville***

The Works Progress Administration (WPA) funded the Chiggerville excavation in 1937, under the direction of Mr David B. Stout and a team from the WPA (Webb and Haag, 1939). The total number of individuals used from the Chiggerville collection (of the 67 adult non-agricultural individuals) was 32 (21 males, 10 females and 1 unknown), with a total of 587 teeth (see Table 5.1). The overall preservation was fairly poor for this collection. Only fragments represented many of the specimens, many of which did not have dentition. The Chiggerville shell mounds were occupational sites and the traffic on the surface, incident to living there, must have resulted in considerable crushing and breaking of the bones that were never buried very deep (Webb and Haag, 1939). These remains are curated at the University of Kentucky, in Lexington, Kentucky.

### ***Indian Knoll***

Indian Knoll was first excavated in 1915 by C.B. Moore for the Academy of Natural Sciences, Philadelphia (Webb, 1974). Over a period of 22 days, 298 skeletons were removed (from Moore, Clarence B. 1916 P.431 in Webb, 1974), making Indian Knoll the largest (894 individuals) and best-preserved (non-agricultural) collection in the Green River Valley group (Snow, 1948). A total of 169 individuals (81 males, 80 females and 8 unknown) were assessed, with 3634 teeth (see Table 5.1). The Indian Knoll collection was one of the best preserved collections of this study and the author looked at as many as time allowed at the university. These remains are curated at the University of Kentucky, in Lexington, Kentucky.

## **5.3 Categories**

The relative proportions of males and females analysed in this project are shown in Table 5.2 along with the number of individuals in each behavioural group, region and number of teeth for each tooth type.



<b>CATEGORIES</b>	<b>TOTALS</b>
<b>SEXES</b>	
Males	413
Females	345
Unknown	132
<b>BEHAVIOURAL GROUPS</b>	
Non-agriculturalists	470
Transitionals	96
Agriculturalists	324
<b>REGION OF COLLECTION</b>	
North America	741
Levant	149
Total number of individuals used in the study	890
<b>TOOTH TYPES</b>	
I1	1638
I2	1886
C	2149
P1	2192
P2	2182
M1	2147
M2	2052
M3	1623
Total number of teeth	15,896

Table 5.2: Number of individuals in each category and number of teeth for each tooth type.

### Summary

The collections used from North America were from the Archaic period (non-agriculturalists), Late Woodland (transitional group) and Mississippian period and Ancient Puebloans (agriculturalists). The small groups from the Levant were from the Late Natufian (non-agriculturalists) and Pre-Pottery Neolithic B (agriculturalists) periods. The total sample size was 890 individuals, divided into 47% males, 39% females, 17% Levantine, 83% North American, 53% non-agriculturalists, 11% from the transitional group and 36% agriculturalists.

## Chapter 6 — Methods

Several different methods were used to record the dental wear as well as estimate age and sex. This goals of this chapter outlines;

- methods used for age-at-death estimation
- methods used for sex estimation
- review two different methods to record occlusal wear
- method used to measure the approximal attrition wear
- method chosen to measured the occlusal wear plane angle
- an overview of the statistical tests used to determine the differences and similarities between the behavioural groups

### 6.1 Age-at-death and sex estimation

It is vitally important to establish age and sex parameters, as mechanical wear is contingent on age, while social factors can only be considered if sex is also assessed.

#### ***Age-at-death estimation methods***

As an individual ages, dental wear increases (Brothwell, 1972, 1981, Hillson, 1986, 1996, Miles, 1963). The age of the individual can help determine the rate at which teeth are worn, or if one group of people wears their teeth faster than another. An independent age estimate is required, based on age-related changes other than the tooth wear and jaw remodelling. In this study, several methods were used. They included:

- cranial suture closure (Meindl and Lovejoy, 1985)
- changes at the auricular surface of the ilium (Meindl and Lovejoy, 1989)
- changes at the pubic symphysis (Brooks and Suchey, 1990).

#### **Cranial suture closure**

This method was first investigated by Dwight (1890, in Cox, 2000), who noted extreme variability in the order and timing of suture closure (from Cox and Mays, 2000). While numerous biologists, archaeologists and anatomists subsequently investigated this phenomenon with a view to linking cranial suture closure and age (Cattaneo, 1937, Cobb, 1952, Hrdlicka, 1939, Parsons and Boc, 1905, Todd and Lyon, 1924, 1925, all from Krogman and Isçan, 1986), the general consensus was that the suture obliteration process was unreliable and erratic. However, by the mid 1980's Meindl and Lovejoy (1985) developed an innovative method for age determination (using a sample of 236 crania of

known age and sex from the Hammann–Todd collection) based on the degree of ectocranial suture closure of the cranial vault and the lateral aspect of the skull (Schwartz, 1995). Today, most researchers believe that suture closure age estimates are only useful when other methods cannot be used, or when they are utilised in conjunction with other methods (Buikstra and Ubelaker, 1994, Key et al., 1994, Meindl and Lovejoy, 1985). The latter stance is that adopted in the present study, suture obliteration being recorded using the Meindl and Lovejoy (1985) method. Table 6.1 shows the scores and descriptions employed by Meindl and Lovejoy (1985), as summarised in *Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker, 1994).

STAGE	SCORE	DESCRIPTION
	Blank	Unobservable.
Open	0	There is no evidence of any ectocranial closure at the site.
Minimal closure	1	Some closure has occurred. Score is assigned to any minimal to moderate closure, i.e. from a single bony bridge across the suture to about 50% synostosis at the site.
Significant closure	2	There is a marked degree of closure but some portion of the site is still not completely fused.
Complete obliteration	3	The site is completely fused.

Table 6.1: Meindl and Lovejoy (1985) scores and descriptions from Buikstra and Ubelaker (1994).

Table 6.2 contains descriptions of each landmark as described by Meindl and Lovejoy (1985), while Figure 6.1 shows the location of these landmarks.

SITE	POINT	DESCRIPTION
Ectocranial sutures	These points should be scored in 1 cm in length and left side used on bilateral segments. If the left is not present then use the right.	
1	Midlambdoid	Mid point of left half of the lambdoid suture.
2	Lambda	At lambda of lambdoid and sagittal sutures.
3	Obelion	At obelion of the sagittal suture.
4	Anterior sagittal	Point on the sagittal suture 1/3 distance from bregma to lambda.
5	Bregma	At bregma (point where coronal and sagittal sutures meet).
6	Midcoronal	Midpoint of the left coronal suture.
7	Pterion	At pterion, within the region of the upper portion of the left greater wing of the sphenoid, usually at the point at which the parietosphenoid suture meets the frontal bone.
8	Inferior sphenotemporal	Point of intersection between the left sphenotemporal suture and a line connecting both articular tubercles of the temporomandibular joint.
10	Superior sphenotemporal	Point on the left sphenotemporal suture lying 2 cm below juncture with the parietal bone.

Table 6.2: Descriptions of points for cranial suture age estimation. Table taken from Buikstra and Ubelaker (1994).

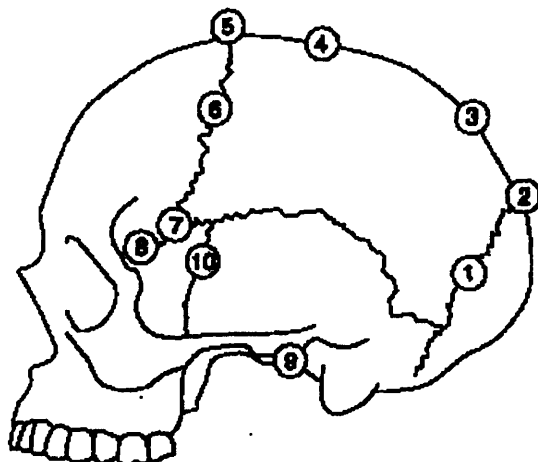


Figure 6.1 Location of the cranial suture points as described in Buikstra and Ubelaker (1994) and Meindl and Lovejoy (1985).

A composite score was taken for the vault sites (midlambdoid, lambda, obelion, anterior sagittal and bregma) and the lateral-anterior sites (pterion, midcoronal, spheno-frontal, inferior spheno-temporal, superior spheno-temporal). Compiled scores from these vault land mark sites were compared to the Meindl and Lovejoy (1985) table in order to obtain an 'S' score that was then later used to determine the age range (Figure 6.2 and Table 6.3).

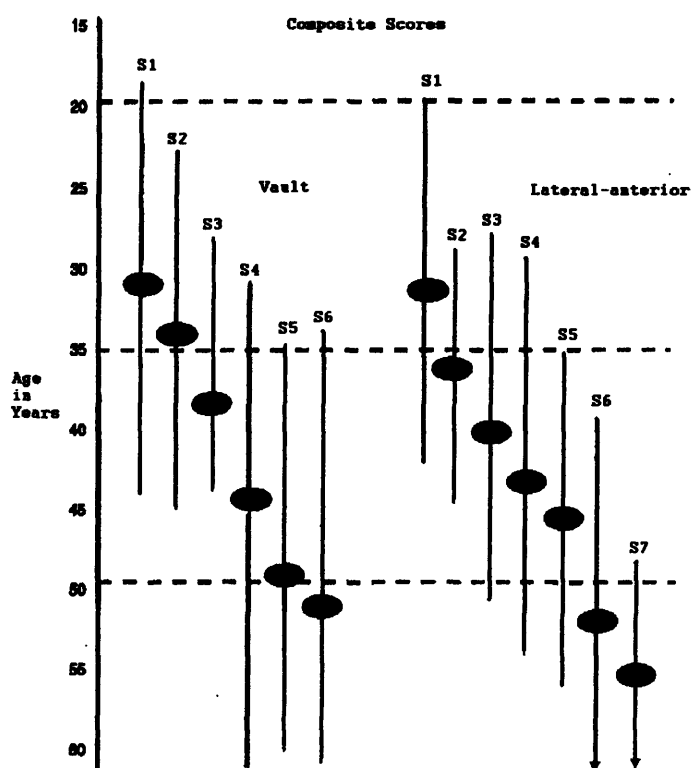


Figure 6.2: Composite scores from Meindl and Lovejoy (1985) reproduced from Buikstra and Ubelaker (1994). Bars denote the interdecile range, with the mean indicated by an oval.

VAULT		LATERAL-ANTERIOR	
Composite score	'S'	Composite score	'S'
1-2	S1	1	S1
3-6	S2	2	S2
7-11	S3	3-5	S3
12-15	S4	6	S4
16-18	S5	7-8	S5
19-20	S6	9-10	S6
		11-14	S7

Table 6.3: Composite scores of the cranial suture closure

While the cranial suture closure method is convenient in being very easy to apply, one major drawback is the large error range per estimate. As recommended in Meindl and Lovejoy (1985), the suture obliteration method was only used in collaborative age estimations (in conjunction with the auricular surface and pubis symphysis) and was only used to provide the most general age range if no other age determination method could be applied.

#### **Auricular surface of the ilium**

Age-related changes in the auricular surface of the ilium were first noted by Sashin (1930, from Krogman and Isçan, 1986) and then re-evaluated by Kobayashi (1967, from Krogman and Isçan, 1986). However, while these authors described general changes related to age in the auricular surface, it was not until the work of Lovejoy and colleagues (1985) that an applicable system was developed to accurately estimate age-at-death from the auricular area (Krogman and Isçan, 1986). The morphological changes accumulate with age, and are apparently independent of osteoarthritic or osteophytic change (Schwartz, 1995). As the sacro-iliac joint is very complex, estimating age-at-death from the auricular surface is more difficult than for the pubic symphysis (see below). It is, however, very important for bioarchaeologists, as it is often very well preserved archaeologically (Buikstra and Ubelaker, 1994, Krogman and Isçan, 1986, Schwartz, 1995).

In this study, each auricular surface was assigned one of the eight phases described by Ubelaker (1989), which are based upon earlier work by Lovejoy *et al.* (1985) and Meindl and Lovejoy (1989). These eight age classes defined in Table 6.4 reflect those laid out in Buikstra and Ubelaker (1994).

PHASES	AGE RANGE (years)	DEFINITIONS
Phase 1	20–24	Transverse billowing and very fine granularity. Articular surface displays fine granular texture and marked transverse organisation. There is no porosity, retro-auricular or apical activity. The surface appears youthful because of broad and well-organised billows, which impart the definitive transverse organisation. Raised transverse billows are well defined and cover most of the surface. Any subchondral defects are smooth-edged and rounded.
Phase 2	25–29	Reduction of billowing but retention of youthful appearance. Changes from the previous phase are not marked and are mostly reflected in slight to moderate loss of billowing with replacement by striae. There is no apical activity, porosity, or retro-auricular activity. Granulation is slightly more coarse.
Phase 3	30–34	General loss of billowing, replacement of striae, and distinct coarsening of granularity. Both demifaces are largely quiescent with some loss of transverse organisation. Billowing is much reduced and replaced by striae. The surface is more coarsely and recognisably granular than the previous phase with no significant changes at the apex. Small areas of micro-porosity may appear. Slight retro-auricular activity may occasionally be present. In general, coarse granulation supersedes and replaces billowing. There is smoothing of the surface by replacement of billows with fine striae, but distinct retention of slight billowing. Loss of transverse organization and coarsening of granularity is evident.
Phase 4	35–39	Uniform coarse granularity. Both faces are coarsely and uniformly granulated with marked reduction of both billowing and striae, but striae may still be present. Transverse organisation is present but poorly defined. There is some activity in the retro-auricular area, but this is usually slight. Minimal changes are seen at the apex, micro-porosity is slight and there is no macro-porosity.
Phase 5	40–44	Transition from coarse granularity to dense surface. No billowing is seen. Striae may be present but are very vague. The face is still partly granular and there is a marked loss of transverse organisation. There is partial densification of the surface with commensurate loss of granularity. There is slight to moderate activity in the retro-auricular area. Occasional macro-porosity is seen, but this is not typical. Slight changes are usually present at the apex. Some increase in macro-porosity is evident, depending on the degree of densification.
Phase 6	45–49	Completion of densification with complete loss of granularity. Significant loss of granulation is seen in most specimens, with replacement by dense bone. No billowing or striae are present. Changes at the apex are slight to moderate but always present. There is a distinct tendency for the surface to become dense. No transverse organisation is evident. Most or all of the micro-porosity is lost to densification. There is increased irregularity of margins with moderate retro-auricular activity and little or no macro-porosity.
Phase 7	50–59	Dense irregular surface of rugged topography and moderate to marked activity in preauricular areas. This is a further elaboration of the previous morphology in which marked surface irregularity becomes the paramount feature. Topography however shows no transverse or other form of organisation. Moderate granulation in only occasionally retained. The inferior face is generally lipped at the inferior terminus. Apical changes are almost invariable and may be marked. Increasing irregularity of margins is seen. Macro-porosity is present in some cases. Retro-auricular activity is moderated to marked in most cases.
Phase 8	60+	Breakdown with marginal lipping, macro-porosity, increased irregularity and marked activity in periauricular areas. The paramount feature is a non-granular, irregular surface with distinct signs of subchondral destruction. No transverse organisation is seen and there is a distinct absence of any youthful criteria. Macro-porosity is present in about 1/3 of all cases. Apical activity is usually marked but it is not requisite. Margins become dramatically irregular and lipped with typical degenerative joint disease. The retro-auricular area becomes well defined with profuse osteophytes of low to moderate relief. There is a clear distinction of subchondral bone, absence of transverse organisation, and increased irregularity.

Table 6.4: Ubelaker (1989) descriptions of the eight phases used in age estimation of the auricular surface taken from Buikstra and Ubelaker (1994).

The auricular surface is generally deemed to be more reliable for estimating age-at-death than cranial suture closure (Krogman and Iscan, 1986). However, identifying the phases can sometimes be difficult owing to the multifactorial nature of the joint in life and it is, of course, also dependent upon the condition of the remains. Like any technique of age-at-death estimation, the auricular surface should be used in conjunction with other methods; if required to be used in isolation, however, it is a more reliable method than cranial suture closure.

### Pubic symphysis

Morphological changes of the pubic symphysis ‘... are considered to be the among the most reliable criteria for estimating age-at-death in adult human remains’ (Buikstra and Ubelaker, 1994). Todd (1920) was the first to examine changes to the articular surface of the pubis (from Krogman and Iscan, 1986), establishing age changes in the pubic

symphysis can be seen as deterioration of the pubic symphyseal surface (Schwartz, 1995). As with all age determination methods, the reliability of this technique is still open to debate, as accuracy is somewhat erratic in certain age groups. The samples Todd (1920) used were entirely male (modern), aged from 18–50 years at death, and fell into 10 age-related phases (Schwartz, 1995). McKern and Stewart (1957) refined Todd's (1920) method by subdividing the pubic symphysis into three components: the symphyseal rim and the dorsal and ventral demifacets (in Schwartz, 1995), and scoring each separately. For the purposes of this research, estimates were based on the Brooks and Suchey (1990) method, which is summarised in detail in Table 6.5 (as presented in Buikstra and Ubelaker, 1994).

PHASE	AGE RANGES (years)		DESCRIPTION
	Male	Female	
Phase 1	15–23	15–24	Symphyseal face has a billowing surface composed of ridges and furrows which includes the pubic tubercle. The horizontal ridges are well marked. Ventral bevelling may be commencing. Although ossific nodules may occur on the upper extremity, a key feature of this phase is the lack of delimitation for either extremity.
Phase 2	19–34	19–40	Symphyseal face may still show ridge development. Lower and upper extremities show early stages of delimitation, with or without ossific nodules. Ventral rampart may begin formation as an extension from either or both extremities.
Phase 3	21–46	21–53	Symphyseal face shows lower extremity and ventral rampart in process of completion. Fusing ossific nodules may form at the upper extremity and extend along the ventral border. Symphyseal face may either be smooth or retain distinct ridges. Dorsal plateau is complete. There is no lipping of the symphyseal dorsal margin or bony ligamentous outgrowths.
Phase 4	23–57	26–70	Symphyseal face is generally fine grained, although remnants of ridge and furrow system may remain. Oval outline is usually complete at this stage. Pubic tubercle is fully separated from the symphyseal face through definition of upper extremity. Symphyseal face may have a distinct rim. Ventral, bony ligament outgrowths may occur in the inferior portion of pubic bone adjacent to the symphyseal face. Slipping may appear on the dorsal border.
Phase 5	27–66	25–83	Slight depression of the face relative to a completed rim. Moderate lipping is usually found on the dorsal border with prominent ligament outgrowths on the ventral border. Little or no rim erosion is present, though breakdown is possible on the superior aspect of the ventral border.
Phase 6	34–86	42–87	Symphyseal face shows ongoing depression as rim erodes. Ventral ligament attachments are marked. Pubic tubercle may appear as a separate bony knob. Face may be pitted or porous, giving an appearance of disfigurement as the ongoing process of erratic ossification proceeds.

Table 6.5: Suchey and Brooks (1990) age estimation from the six phases of the pubic symphysis. Table was taken from Buikstra and Ubelaker (1994).

While sometimes somewhat erratic, the method for estimating age-at-death from the pubic symphysis is one of the most reliable methods currently available. However, this feature is not always well preserved archaeologically, unlike the auricular surface. When the technique was employed in the current study, it gave estimates that correlated well with results derived from auricular surface and the cranial suture closure methods.

### **Description of the age groups**

Table 6.6 describes the scores or phases – and the four age groups to which they pertain – that were used in the present study. In the cranial suture closure method, vault and lateral-anterior score 'S1' refers to the young adult group; vault and lateral-anterior score 'S2' refers to the middle adult 1 group; vault and lateral-anterior scores 'S3 and S4' and lateral-anterior score 'S5' refer to the middle adult 2 group, while vault scores 'S5 and S6' and lateral-anterior scores 'S6 and S7' define the old adult group. The auricular

surface method uses eight phases. Individuals from phase 1 pertain to the young adult group; phases 2 and 3 define the middle adult group 1; phases 4 and 5 refer to the middle adult 2 group, while phases 6–8 define the old adult group. The pubic symphysis system uses six phases, broken down in the same manner as the auricular surface. The first phase refers to young adults, the second to middle adults 1, phase 3 to middle adults 2, and phases 4–6 to the old adult group. Each age-at-death estimation method was run separately, so as to minimise bias. If both the cranium and inornate bones were not present, the age-at-death was not recorded.

AGE GROUP	AGE RANGE (years)	CRANIAL SUTURE SCORES		AURICULAR SURFACE	PUBIC SYMPHYSIS
		VAULT SCORE	LATERAL-ANTERIOR SCORE		
Young adult	20–25	S1	S1	Phase 1	Phase 1
Middle adult 1	25–35	S2	S2	Phases 2 and 3	Phases 2 and 3
Middle adult 2	35–45	S3, S4	S3, S4, S5	Phases 4 and 5	Phase 4
Old adult	45+	S5, S6	S6, S7	Phases 6, 7 and 8	Phases 5 and 6

Table 6.6: Age ranges used in the present study.

### **Sex estimation**

Sex estimation relies upon the reliable detection of sexually dimorphic characteristics in the human skeleton (Brothwell, 1981, Cox and Mays, 2000, Krogman and Iscan, 1986, Mays and Cox, 2000). Assessment of the morphological features of the cranium is both easy to use and quick to carry out (Krogman, 1955), although cranial characteristics are not as sexually dimorphic – and are therefore not as reliable – as those of the pelvis (Phenice, 1969). When data from the cranium and innominate bones are combined, however, the strength of assertions made about gender are increased (Mays and Cox, 2000). Sex-based characteristics are partially age related, appearing or becoming more pronounced at puberty, and many are affected by extreme old age (Krogman and Iscan, 1986, Buikstra and Ubelaker, 1994, Schwartz, 1995).

For this research, sex estimation for all adult individuals was carried out using the morphological features of both the cranium and the innominate bone wherever possible. Cranial sex estimation was based upon morphology rather than metric characteristics (Parsons and Keene, 1920, in Krogman and Iscan, 1986). In basic terms, certain morphological features of the cranium tend to be larger or more robust in males than in females (Buikstra and Ubelaker, 1994). In this project five main attributes of the cranium were used (Acsádi and Nemeskéri, 1970, in Buikstra and Ubelaker, 1994):

- nuchal crest (occipital muscle attachment)
- mastoid process (temporal muscle attachment)
- supra-orbital margin (superciliary arches)



- glabella (supra-nasal protruberance)
- mental protuberance (chin).

The innominate bone has several reliable features for sex estimation. The scored morphological features in the pelvis were the:

- ventral arc
- subpubic concavity
- inferior ramus
- greater sciatic notch.

Phenice (1969) stated that the ventral arc was the most reliable pelvic characteristic for sex determination, while the inferior ramus performed the least well. Phenice later went on to test this theory on 175 pubic bones (Phenice, 1969). His findings included morphological features of the subpubic region were fairly reliable, and could correctly determine sex in 96% of cases (Krogman and Isçan, 1986). Sutherland and Suchey (1991) tested Phenice's methods on a wider age range of individuals and confirmed that the Phenice method had a 96% level of accuracy in sex determination. Figure 6.3 contains diagrams and the scoring systems used for the cranium (Acsádi and Nemeskéri, 1970, in Buikstra and Ubelaker, 1994) and the pubis (Phenice, 1969).

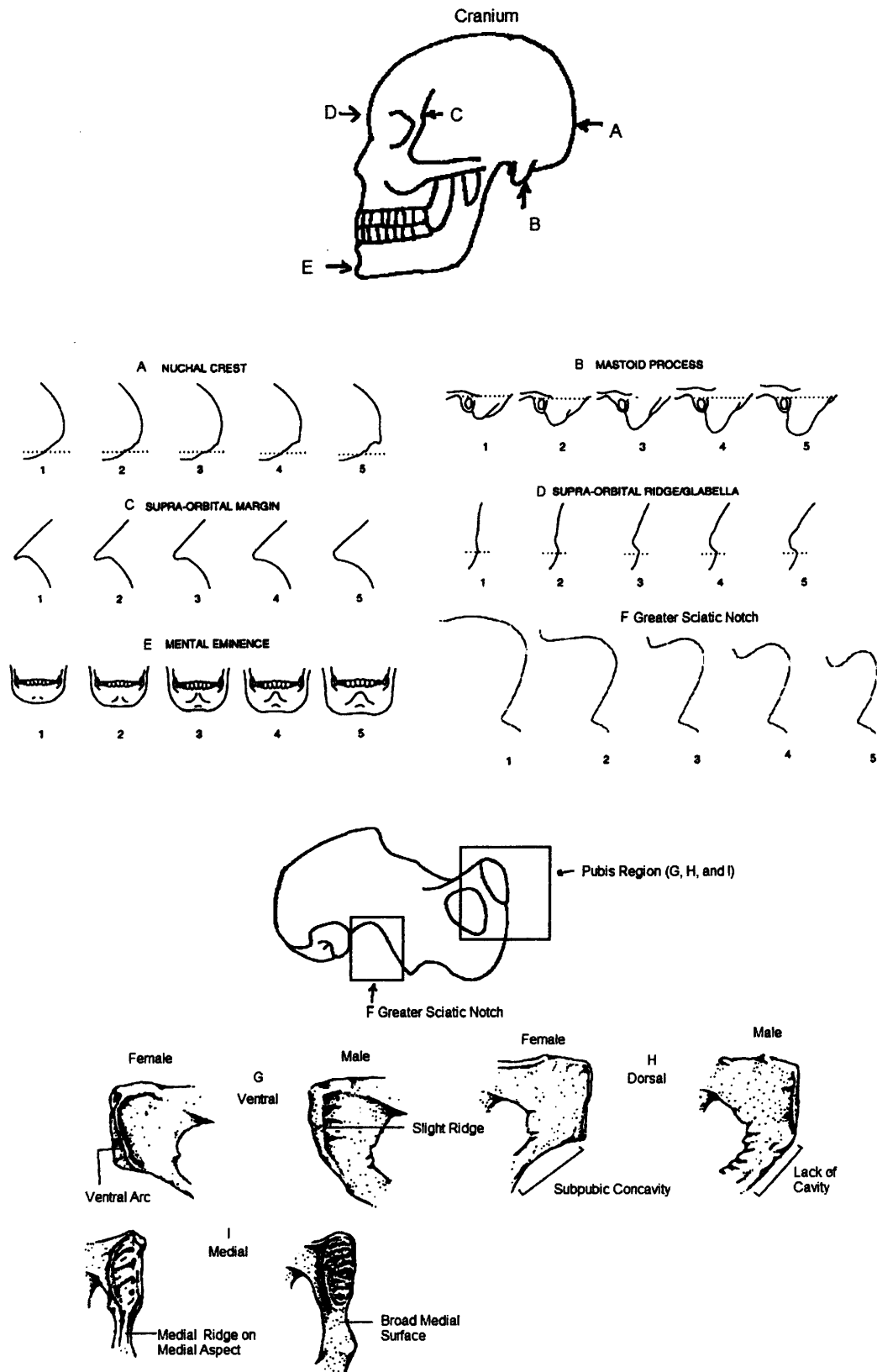


Figure 6.3: Diagrams of the morphological features used to estimate sex (for features A-I numbers correlate to 1= definite female, 2= probable female, 3= unknown sex, 4=probable male, and 5= definite male). (Figures of sex estimation were taken from several sources. The cranium and pelvis taken from Buikstra and Ubelaker (1994), Krogmasn and Isçan (1986) and Schwartz (1995). Specific information from the subpubic region was from Phenice (1969), the cranium region was from Acsádi and Nemeskéri (1970) in Buikstra and Ubelaker (1994) ).

FEATURE	DESCRIPTION OF FEATURE	FEMALE	MALE
<b>Cranial features A-E</b>			
Nuchal crest A	View of the lateral profile of the occipital bone.	Smooth traces of the nuchal line.	Marked to roughened nuchal lines and occipital crest
Mastoid process B	Score of the volume of the mastoid process.	Generally narrower, more pointed, (low/narrow to high/pointed).	Generally more massive, broader, stubbier (high/massive to broad/stubby and low).
Supra-orbital margin C	Feeling the margin of the orbit at the lateral aspect of the supra-orbital foramen..	Sharp, thin superior edge.	Blunt, thick superior edge.
Supra-orbital Ridge D	Viewing the cranium from the side to study the profile of the frontal bone.	Flat to moderately swollen.	Moderate to prominent swelling.
Mental protuberance E	Observation of the projection of the mental protuberance (chin).	Rounded, smooth to somewhat delineated.	Pronounced protuberances, protruding triangle or inverted 'T'.
<b>Pelvic features F-I</b>			
Greater sciatic notch F		'U' shaped, broader, shallower, more open, more obtuse angle.	'V' shaped, narrower, deeper, more closed, more acute angle.
Ventral arc G	An elevated ridge of bone across the ventral surface of the pubis. The pubis needs to be orientated with the ventral surface directly facing the observer.	Ridge is present due to being a secondary sex characteristic.	Not present in males.
Subpubic concavity H	Found on the ischiopubic ramus lateral to the symphyseal face. Need to view from the dorsal surface.	More obtuse (80–85°), rounded, more 'U' shaped.	More acute (50–60°), narrow and more 'V' shaped.
Inferior ramus I	The medial surface of the ischiopubic ramus immediately below the symphysis.	More gracile, tapers towards the pubic symphysis, roughened, edge everted.	Deeper, flatter anterior surface

Table 6.7: Compiled descriptions of sex estimation were taken from several sources. The cranium and pelvis taken from Buikstra and Ubelaker (1994), Krogmasn and Isçan (1986) and Schwartz (1995). Specific information from the subpubic region was from Phenice (1969), the cranium region was from Acsádi and Nemeskéri (1970) in Buikstra and Ubelaker (1994).

The five sex classifications for the cranium and four for the pelvis were based on the 1–5 scale from *Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker, 1994), from stage 1 (definitely female) to stage 5 (definitely male). The full system is summarised in Table 6.7. Like the age estimation methods, sex estimation techniques were scored independently of one another. If both the cranium and innominate bones were not present, that individual was recorded as being of 'unknown sex' (Table 6.8).

SCORE	SEX
1	Definite female
2	Probable female
3	Unknown sex
4	Probable male
5	Definite male

Table 6.8: Scores from the sex estimation.

## 6.2 Dental scoring systems

The dental wear characteristics that were recorded include occlusal attrition wear, approximal attrition wear and the occlusal wear plane angle. An array of techniques were used to record these features.

### *Occlusal attrition*

Various researchers (Campbell, 1939, and Heithersay, 1960, in Hillson, 1996) have employed a wear-scoring technique based on Broca (1879, in Walker *et al.*, 1991). This

technique is based on a five-stage scale, visually ranking how much dentine has been exposed by the process of attrition (Walker *et al.*, 1991). Murphy (1959b) devised a technique to illustrate the tooth wear gradient in an array of commonly occurring forms, in order to determine the pattern of dentine exposure with increasing tooth attrition, and the degree of difference in dentine exposure between the molar teeth (Murphy, 1959a). This research was the starting point for many studies of the attrition process in humans (Brothwell, 1963a, 1963b, Schmucker, 1985, Smith, 1984), leading to an array of more elaborate systems (Molnar, 1971, Scott, 1979a, 1979b). The method of attrition scoring used in the current project follows the Smith method (1984) – adapted from Murphy (1959a, 1959b) and is both more recent and more commonly used than the Molnar technique. There are eight stages of wear that range from stage 1 (no wear at all) to stage 8 (enamel is not present, except possibly for a slight enamel rim around the edge of the tooth). The diagrams of the crown surfaces (Figure 6.4) were used in conjunction with the description of the wear stages that are summarised in Table 6.9 (from Smith, 1984).

	MOLARS	PREMOLARS	INCISORS AND CANINES
STAGE 0	Missing and cannot be recorded.		
STAGE 1	Unworn to polished or small facets (no dentine).		
STAGE 2	Moderate cusp removal (blunting). Thinly enamelled tooth may show cusp dentine but human permanent molars show no more than one or two pinpoint exposures.	Moderate cusp removal (blunting).	Point or hairline of dentine exposure.
STAGE 3	Full cusp removal and/or some dentine exposure, pinpoint to moderate	Full cusp removal and/or moderate dentine patches	Dentine line of distinct thickness
STAGE 4	Several large dentine exposures still discrete.	At least one large dentine exposure on one cusp.	Moderate dentine exposure no longer resembling a line.
STAGE 5	Two dentinal areas coalesced.	Two large dentine area (may be slight coalescence).	Large dentine area with enamel rim complete.
STAGE 6	Three dentinal areas coalesced, or four coalesced with enamel island.	Dentinal areas coalesced, enamel rim still complete.	Large dentine area with enamel rim lost on one side or very thin enamel only.
STAGE 7	Dentine exposed on entire surface, rim largely intact.	Full dentine exposure, loss of rim on at least one side.	Enamel rim lost on two sides or small remnants of enamel remain.
STAGE 8	Severe loss of crown height, breakdown of enamel rim: crown surface takes on shape of roots.	Severe loss of crown height: crown surface takes on shape of roots.	Complete loss of crown, no enamel remaining; crown surface takes on shape of roots.

Table 6.9: Smith (1984 p. 45) wear stages.

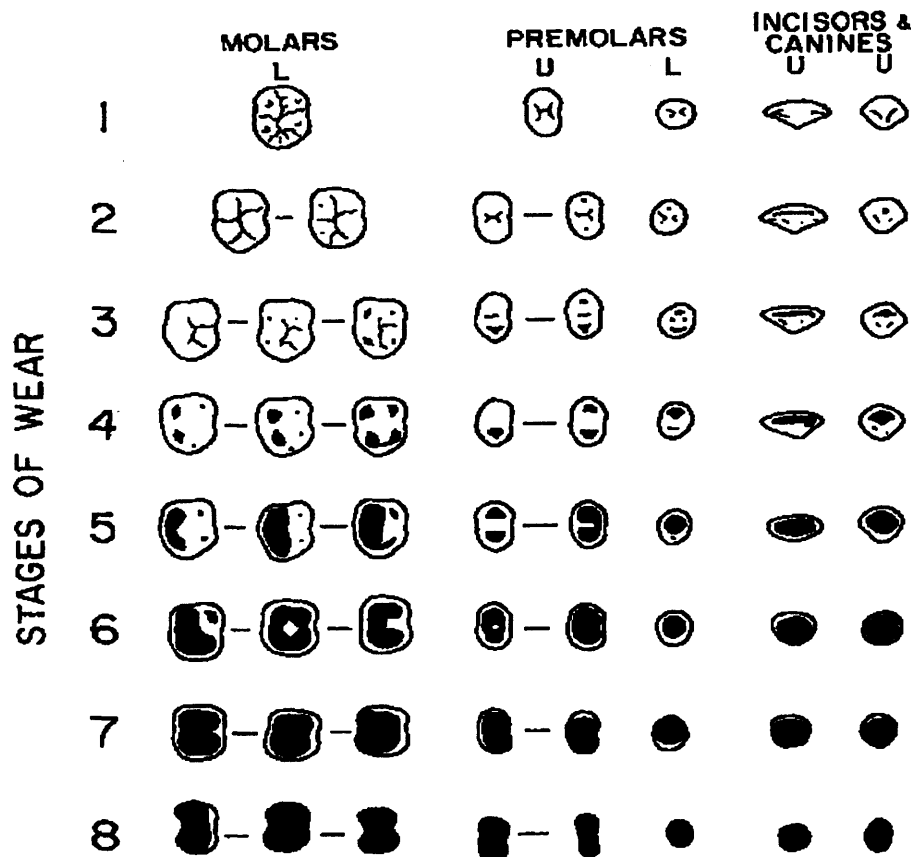


Figure 6.4: Diagram of the crown surfaces used to score stages of tooth wear. Taken from Smith (1984:pg 46).

The Smith method is an ordinal scoring system that does not require elaborate equipment, and that permits the rapid accumulation of data. All teeth from the maxilla and mandible are recorded. If the tooth is not present, the score is zero. If the tooth is present but could not be recorded due to the presence of caries, cracked or chipped enamel, the pathology is stated but the tooth is not used in the final count. However, use of ordinal techniques is not necessarily appropriate for dental wear applications. Lunt (1978) suggested that inter-population comparisons be recorded as gradients (Hillson, 1996). With ordinal data, standardisation becomes more difficult, differences between wear classes become subjective and data may not be comparable between researchers (Walker *et al.*, 1991). As stated by Lunt (1978), 'the repeatability of observations made by a single investigator is sometimes poor'. Therefore in order to record dentine exposure on an interval scale, the amount of dentine exposed through occlusal attrition wear was converted into a percent of the total tooth surface.

This follows work carried out by Richards and Brown (1981), who took photographs of dental casts of Australian aborigines from the Kuini, Kulari, Walambi and Warmala tribes living at the Kalumburu Benedictine Mission, the Aranda tribe from the Haasts Bluff and Wailbri subjects from Yuendumu. Forty-one individuals of known age

and sex were assessed and dental attrition was measured as a ratio of exposed dentine to total crown area when viewed from the occlusal surface (Behrend, 1977, Richards and Brown, 1981):

Dental casts were photographed with the occlusal plane defined by the central fossae of the second molars and the incisal edges of the central incisors, parallel to the focal plane of the camera. The images were then traced on paper and the outlines of tooth crown and exposed dentine were compared with the original casts to ensure an accurate reproduction of the pattern of dentine exposure (Richards and Brown, 1981 pg 94-95).

These images were scanned using a digitiser programmed for use as a planimeter, in order to record the amount of dentine exposure and relate it to the total area of the occlusal surface (Richards and Brown, 1981).

As this method collected occlusal wear data as a continuous measurement, it transcended the constraints and potential inconsistencies of ordinal scales. In the present study, therefore, the author employed a new method based upon the Richard and Brown technique. However, several practical and technological changes were made. The steps involved in recording the dentine exposure were as follows:

- **Step 1.** A colour digital image was taken using a Canon ProShot 3.3 megapixel digital camera. The camera was held parallel to the occlusal plane of the tooth. A separate image was taken for each of the right and left, upper and lower sections of the jaw. Teeth were grouped as anterior teeth, (I1, I2 and C) and cheek teeth, (P1 and P2). Because of the natural tilt of the molars, it was necessary to take single images for each of the molars to ensure the lens of the camera was constantly parallel to the occlusal surface.
- **Step 2.** The images were downloaded into the SigmaScan Pro 5 digital imaging software program, a sophisticated image analysis application designed to modify, enhance and measure digital images. SigmaScan Pro 5 provided several measurement techniques, which can be applied either manually or automatically. This program counted the pixels, (derived from 'picture element'), which are the smallest units of a digitised image, and imported this number into a spreadsheet.
- **Step 3.** This step counted the number of pixels in the area of exposed dentine and the total area of the occlusal surface. Several different methods were tested to determine how best to define the edge between enamel and dentine. It was found that manipulation of the contrast, increasing the colours by 5–10% and magnifying the image  $\times 2$  helped considerably to distinguish the difference

between enamel and dentine. However, this procedure was not necessary for all images. To determine the area of dentine, the mouse was used to draw a line around the edge where the dentine met the enamel. Once the desired area of the occlusal surface was defined, the 'fill' icon from the toolbar was used to highlight the exposed dentine. The program then counted the number of pixels in the highlighted area, and transferred this information into the spreadsheet. These steps were then repeated to define total occlusal surface area (for which digital manipulation of the image was not required).

- **Step 4.** The dentine exposure was calculated as a ratio of the area of exposed dentine over the total occlusal surface (Behrend, 1977). This measurement was referred to as the dentine percent, and allowed individual teeth to be compared to one another without the bias of variable tooth size. Each pixel count was repeated three times to ensure accuracy. Teeth were not included if the occlusal surfaces were chipped, broken, or showed evidence of surface caries. Figures 6.5–6.7 illustrate the steps 1, 3a and 3b.

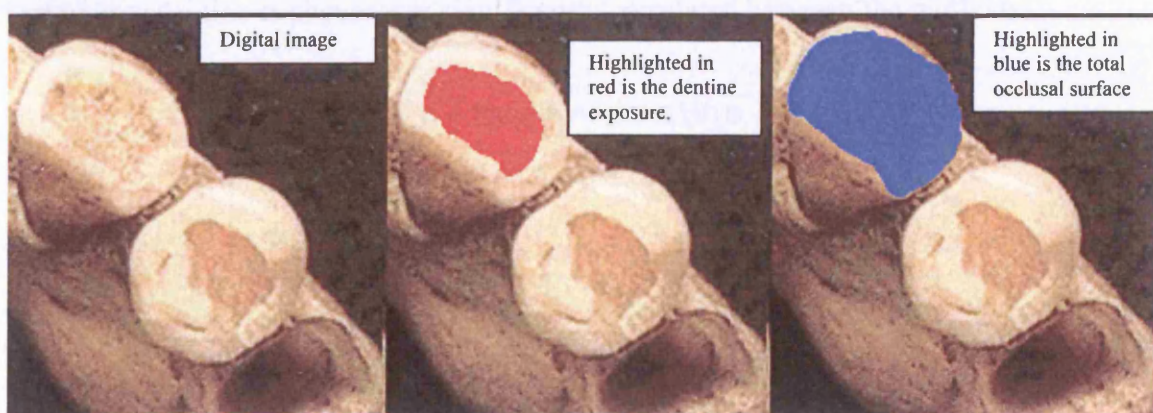


Figure 6.5: Step 1

Figure 6.6: Step 3a,

Figure 6.7: Step 3b

### Comparison of the two methods

The Smith and dentine percent methods were compared to assess the merits of ordinal versus interval data. Measurements were taken from the lower right jaw (I1, P1 and M1).



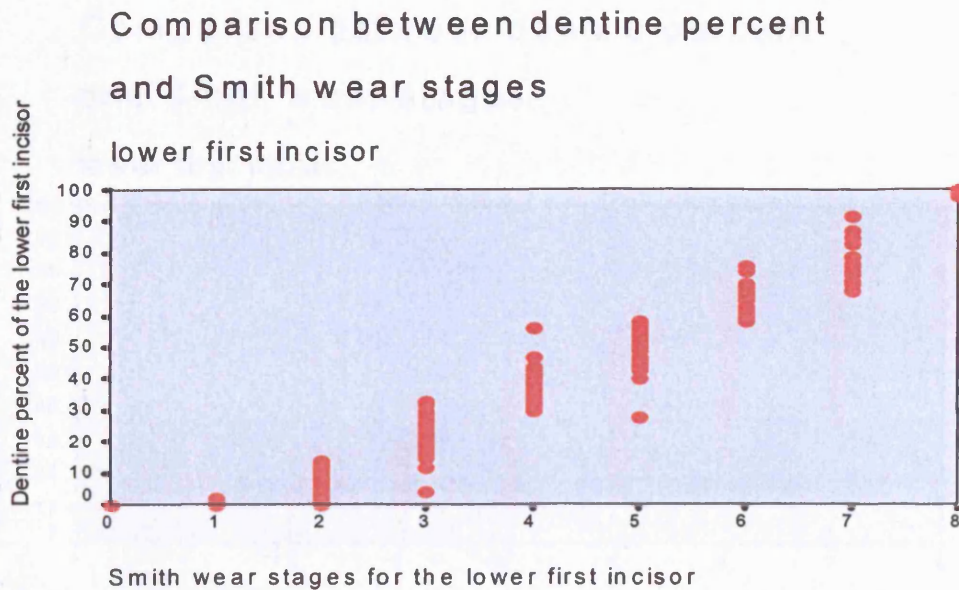


Figure 6.8: Scatter plot of the dentine percent compared to the Smith wear stages for the lower first incisor.

Figure 6.8 shows that as the stages of the Smith method increased, so did the percent of dentine in the lower first incisor. It should be noted, however, that the dentine percent overlapped between stages. For example, in the Smith stage 4, the dentine percent overlapped with stages 3 and 5. In the correlation coefficient table (Table 6.10 below), first incisor dentine exposure was significantly correlated between the methods.

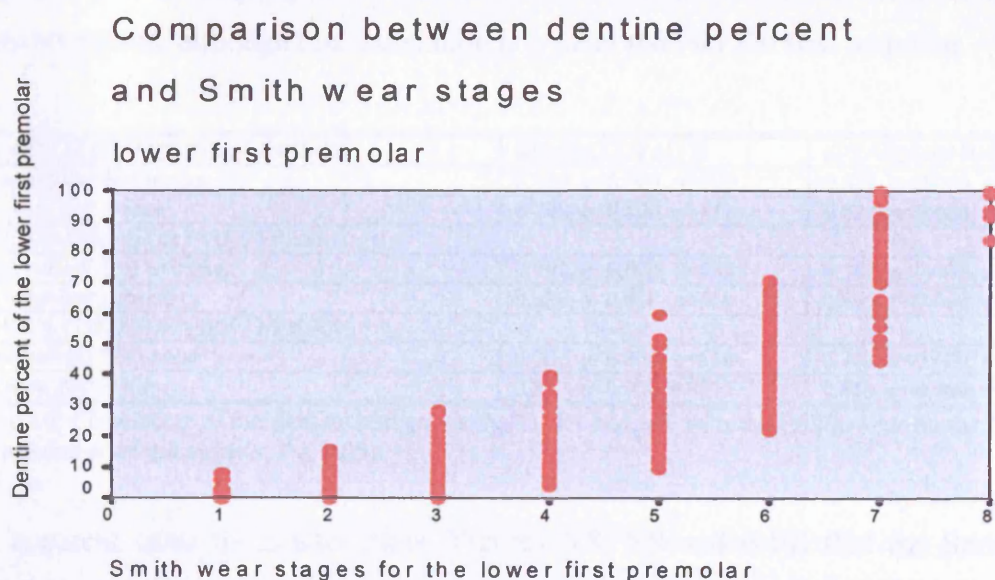


Figure 6.9: Scatter plot of the dentine percent compared to the Smith wear stages for the lower first premolar

The first premolar showed a greater overlap between dentine percent and the Smith stages (Figure 6.9). Smith stage 4 overlapped with stages 1, 2, 3, 5, and 6. Table 6.10 shows that the methods were still strongly correlated.



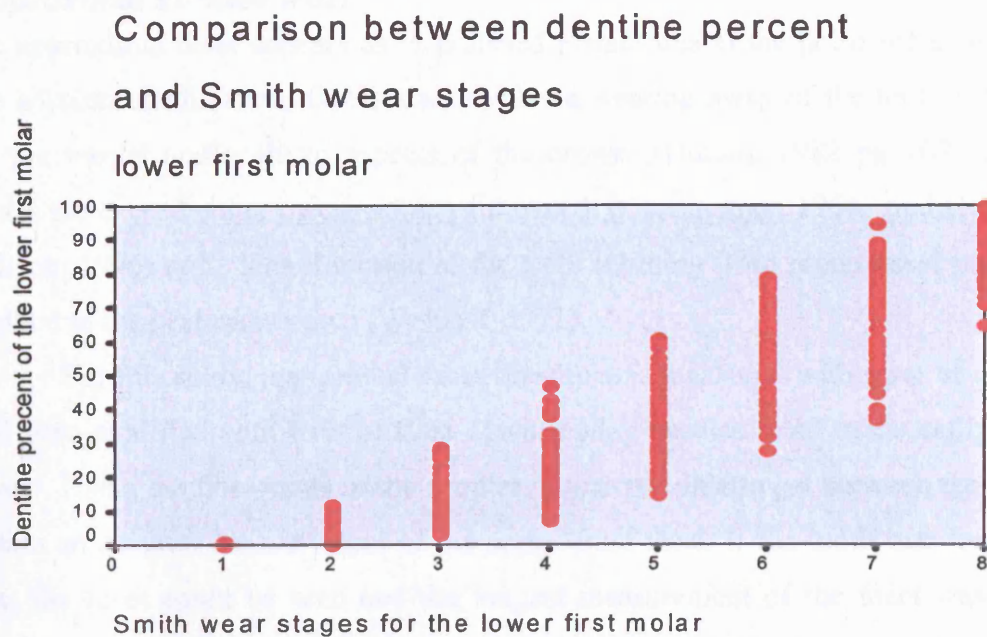


Figure 6.10: Scatter plots of the dentine percent compared to the Smith stages for the lower first molar.

Scatter plot Figure 6.10 shows a greater overlap between each of the occlusal scoring stages for the lower first molar, as Smith stage 4 overlapped with stages 2, 3, 5, 6 and 7. From this, it would appear that the technique becomes less accurate as one moves distally along the tooth row (presumably a reflection of the anatomical and mechanical complexity of molar teeth). In the correlation table (Table 6.10), the methods were still highly correlated, although this correlation is weaker than for the first premolar.

METHODS USED FOR FIRST INCISOR	KENDALL TAU B	SPEARMAN RHO
Dentine percent first incisor	0.708, $p < 0.000$ , $n = 399$	0.822, $p < 0.000$ , $n = 399$
Smith wear first incisor	0.708, $p < 0.000$ , $n = 412$	0.822, $p < 0.000$ , $n = 412$
METHODS USED FOR FIRST PREMOLAR		
Dentine percent first premolar	0.792, $p < 0.000$ , $n = 555$	0.792, $p < 0.000$ , $n = 555$
Smith wear first premolar	0.889, $p < 0.000$ , $n = 568$	0.889, $p < 0.000$ , $n = 568$
METHODS USED FOR FIRST MOLAR		
Dentine percent first molar	0.762, $p < 0.000$ , $n = 556$	0.762, $p < 0.000$ , $n = 556$
Smith wear first molar	0.853, $p < 0.000$ , $n = 569$	0.853, $p < 0.000$ , $n = 569$

Table 6.10: Correlation of the dentine percent on the I1, P1 and M1 with the Smith wear on the I1, P1 and M1. ( $n$ =number of individuals,  $P \leq 0.05$ ).

It is apparent from the scatter plots (Figures 6.8, 6.9 and 6.10) that the Smith stage method is not an efficient or accurate way to express dentine exposure. As stated earlier by Lunt (1978), it would indeed appear that attrition wear needs to be recorded as a gradient if inter-population studies are to have any meaning. Because of the overlap between the Smith stages, the digital method was deemed to be a more accurate method for measuring dentine exposure, and thus for evaluating occlusal attrition wear.

***Approximal surface wear***

An approximal facet appears as 'a polished planar area at the points of contact between the adjacent teeth. These facets also involve a wearing away of the tooth substance, but on the mesial and/or distal aspects of the crown' (Hinton, 1982 pg 103). Approximal facets are caused either by crowding of the teeth (Oppeheimer, 1964, and Hunt, 1960, in Hillson, 1996) or by lateral motion of the teeth resulting from pronounced pressure being applied to the occlusal surface (Wolpoff, 1971).

For this study, approximal facet breadth was measured with a set of callipers that had been modified with a set of filed-down sewing needles fixed to the calliper tips with epoxy. Using the fine points of the needles, it was possible to get between the teeth and to obtain an accurate measurement of the approximal facet. If the tooth was loose from the jaw, the facet could be seen and the longest measurement of the facet was taken. The breadth of the approximal facet was measured on the mesial surface of each tooth.

***Occlusal angle measurement:***

Some researchers have used the helicoidal plane to estimate age (Butler, 1972) while other studied the relationships between dental attrition and the helicoidal plane (Hall, 1976). Butler (1972) investigated 136 individuals and showed that several patterns of the occlusal attrition plane were positively correlated with age. Hall (1976) used several quantitative techniques to demonstrate that the helicoidal plane developed with occlusal attrition. Finally, Smith (1984) stated that the gradient of the occlusal wear plane angle matched occlusal surface wear, thus suggesting that the angulation of the occlusal wear plane correlated with the rate and extent of occlusal attrition.

In this study, the angle of the occlusal surface was measured relative to the horizontal occlusal plane, using a modified protractor similar to that used by Smith (1984), Butler (1972) and Hall (1976). The angle device was made from a metal protractor with a ruler along the base, and a level to ensure accuracy (see Figure 6.11). The occlusal surface angles were recorded to the nearest 0.5°. Slopes to the buccal side were recorded as positive, while slopes to the lingual side were recorded as negative. Occlusal surface angles were recorded on upper/lower, right/left first and second molars. The many variable axial tilts of the third molar precluded accurate recording, and this tooth was therefore not scored for plane angulation. Unworn teeth were measured from cusp to cusp. The base of the ruler was balanced on the most mesial-lingual cusp with the other end of the ruler in position on the opposite cusp of the tooth on the other side of the jaw. In order to minimise discrepancies, it was very important to ensure that the arm was parallel to – rather than resting upon – the occlusal surface. If the corresponding tooth on



the opposite side of the jaw was not present, the tool had to be held parallel to the work surface and checked with the level. If the tooth was loose from the bone, partly extruded from its socket during life, or obviously destroyed by dental caries, it was not measured.

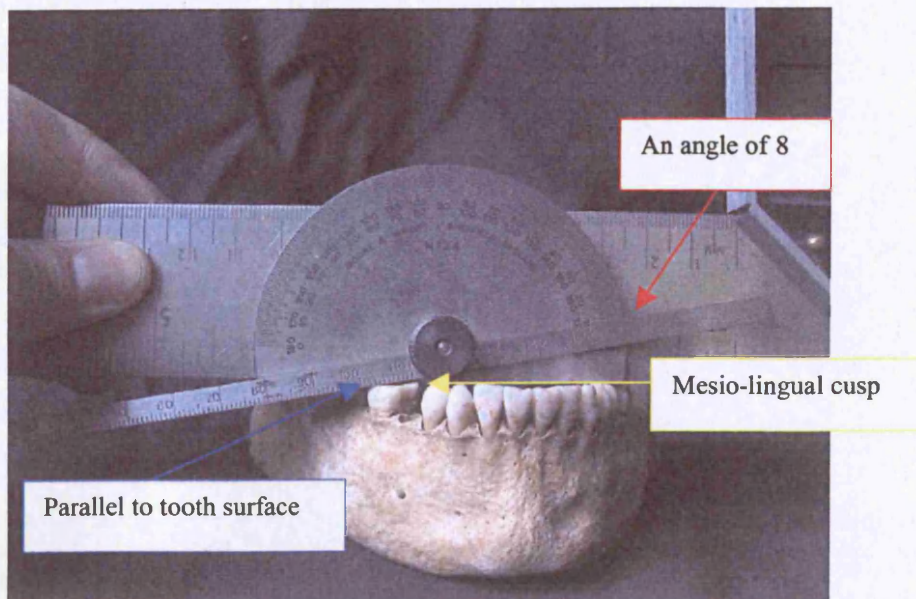


Figure 6.11: The use of the occlusal angle measuring tool.

The measurements for each of the dental methods (dentine exposure, approximal attrition measurement and occlusal wear plane angle) were taken three times per tooth to ensure accuracy. When a tooth was not present – or when the tooth could not be scored owing to chipping, breakage or pathology – this was recorded, but the tooth was not used in the study.

### 5.3 Statistical analysis

SPSS (Statistical Package for the Social Sciences) was used for all statistical analysis. SPSS is a comparative system for analysing data, which provides a statistical analysis and data-management system in a graphical environment, using descriptive menus and dialogue boxes to carry out most of the calculations.

Simple scatter plots were run to plot each tooth to the M1 dentine percent. A scatter plot determines whether there is a relationship between the variables, the nature of any such relationship, and whether any cases are markedly different from the others. Figure 6.12 shows a sample scatter plot and how to read it. In each of the scatter plots, the dentine percent is always expressed as a percent, the approximal facet is expressed as millimetre (mm) and the occlusal wear plane angle is expressed as degrees.

## Comparison of the lower second incisor and first molar

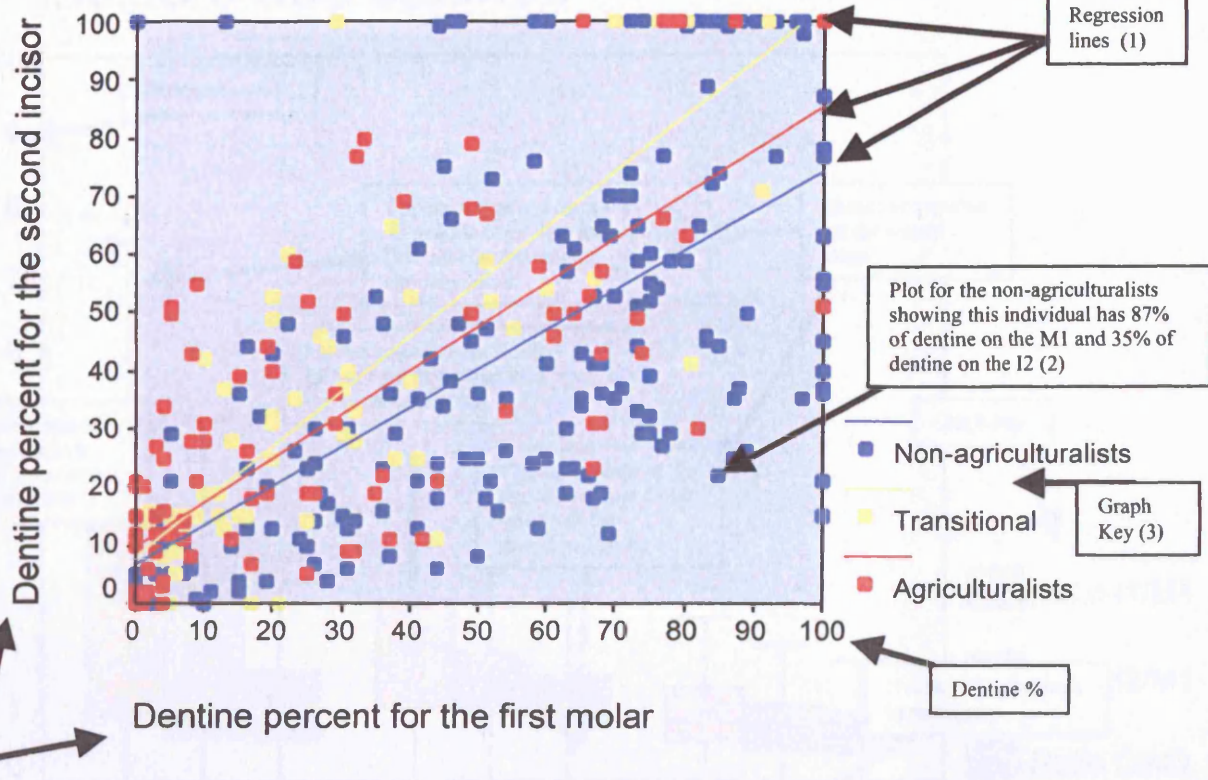


Figure 6.12: Sample scatter plot. The upper right box is pointing to the regression lines. In some of the scatter plots, regression lines were used to better show the relationship between the collections. The second box is pointing to a single plot. This plot represents an individual that has dentine exposure on the occlusal surface of the first molar at 87% and dentine exposure of 35% on the second incisor. Each behavioural group is illustrated with a different colour which is standard throughout the results chapter.

Box plots or box-and-whisker plots present the data in a different way from the scatter plots. The whiskers or lines above and below the box indicate the range of the scores. The box in the centre of the lines shows the interquartile range, with the dark line in the middle being the median, and the whiskers or the 'T' shaped lines protruding from the top and bottom denoting the first and third quartiles also called the overall range (Carver and Nash, 2000). See Figure 6.13 for further details.



## Box plot of dentine percent for incisors and canines

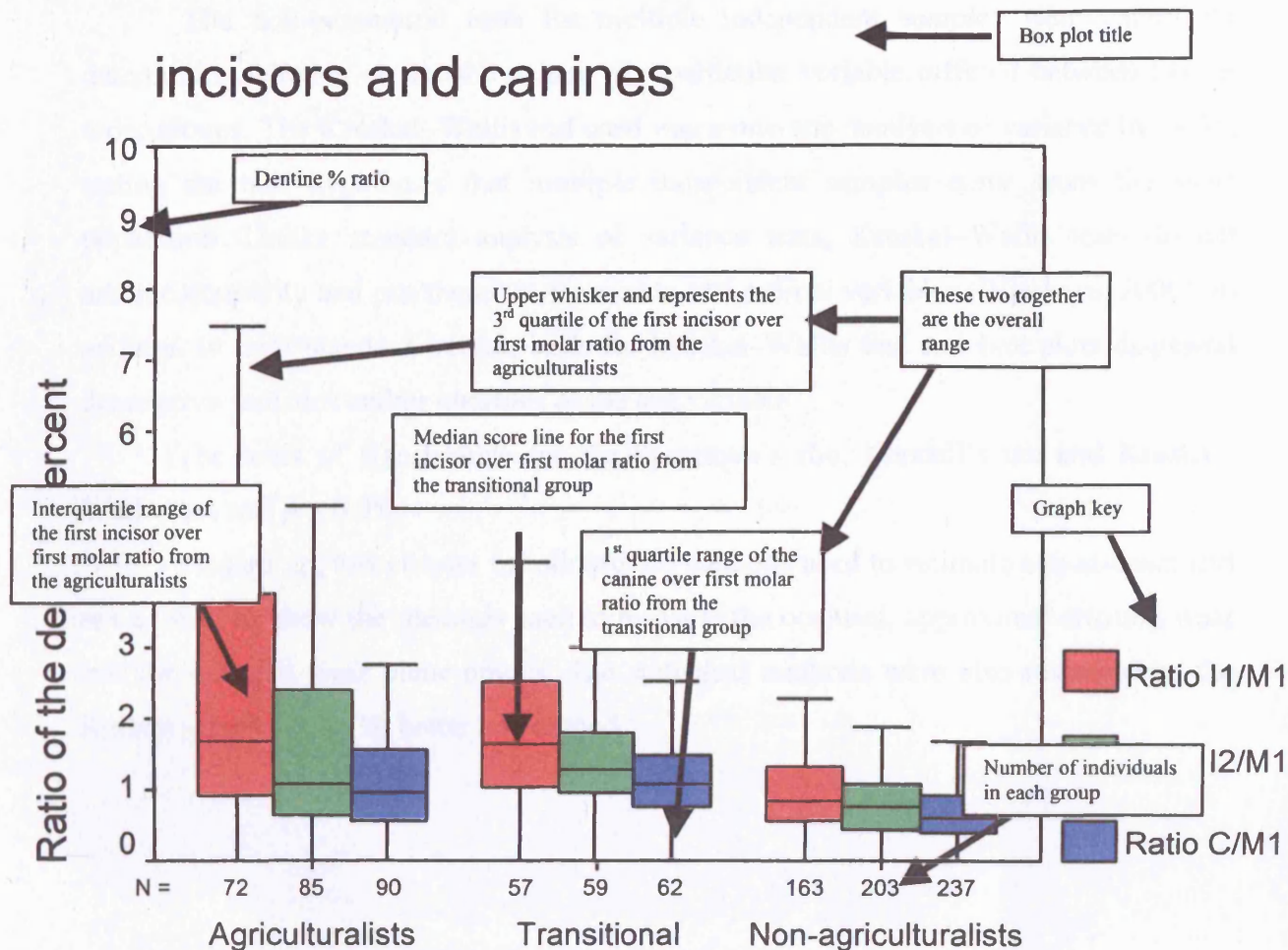


Figure 6.13: Sample box plot. Boxes illustrate which whiskers are the 1<sup>st</sup> and 3<sup>rd</sup> quartiles, the inter-quartile range and the median score. The rest of the boxes explain other parts of the graph. A ratio used were always over the first molar (M1), therefore this graph shows box plots for the first incisor (I1) over the first molar dentine percent, the second incisor (I2) over the first molar dentine percent and the canine (C) over the first molar dentine percent.

Statistical tests were run in order to determine the relationship between each of the four sections of the jaw (upper right, upper left, lower right and lower left). The upper right was compared to the upper left, the lower right to the lower left and the lower right to the upper right. The data from this project were non-parametric. Therefore the Spearman's rho and Kendall's tau b tests were used to determine the correlation coefficient of the quadrants.

The Spearman's rho test works by ranking the data and then applying Pearson's equation to those ranks (Field, 2000). The coefficient in this equation is known as the Pearson product-moment correlation coefficient. By standardising the covariance, the remaining value has to lie between -1 and +1; the closer to +1 the correlation coefficient score is, the more likely it is that the two variables are similar (Field, 2000 pg 75). The Kendall's tau test is used when the data set is small, but with a large number of tied ranks.

It was suggested (Field, 2000) that the Kendall's statistic provides a better estimate of the correlation, and facilitates the extrapolation of more accurate generalisations.

The non-parametric tests for multiple independent samples were useful for determining whether or not the values of a particular variable differed between two or more groups. The Kruskal–Wallis test used was a one-way analysis of variance by ranks, testing the null hypothesis that multiple independent samples come from the same population. Unlike standard analysis of variance tests, Kruskal–Wallis tests do not assume normality and can therefore be used to test ordinal variables (Windows, 2000). In addition to their standard output, both the Kruskal–Wallis test and box plots displayed descriptive statistics and/or quartiles of the test variable.

The level of significance for the Spearman's rho, Kendall's tau and Kruskal–Wallis test was  $p \leq 0.05$ .

To sum up, this chapter introduced the methods used to estimate age-at-death and sex as well as show the methods used to measure the occlusal, approximal attrition wear and the occlusal wear plane angles. The statistical methods were also reviewed so the Results chapter 7 can be better understood.

## Chapter 7—Results

Questions outlined in Framework and Hypothesis chapter 4 are addressed below and organized in the following sections:

- 7.1: Left-right differences (7.1.A), age (7.1.B) and gradients of wear (7.1.C)
- 7.2: Comparison between the non-agriculturists, transitional group and agriculturalists.
- 7.3: Intra-behavioural group evaluation of the non-agricultural assemblages.
- 7.4: Intra-behavioural group evaluation of the agricultural assemblages.

### 7.1.A Comparison of the lower right and left teeth

It was necessary to know if the four quadrants of the jaw could be studied independently or if one quadrant can represent each individual.

#### Dentine percent

For all jaws in which a left-right pair of teeth is presented, the dentine percent for the left tooth is plotted below against the dentine percent for the right tooth, for each lower tooth type.

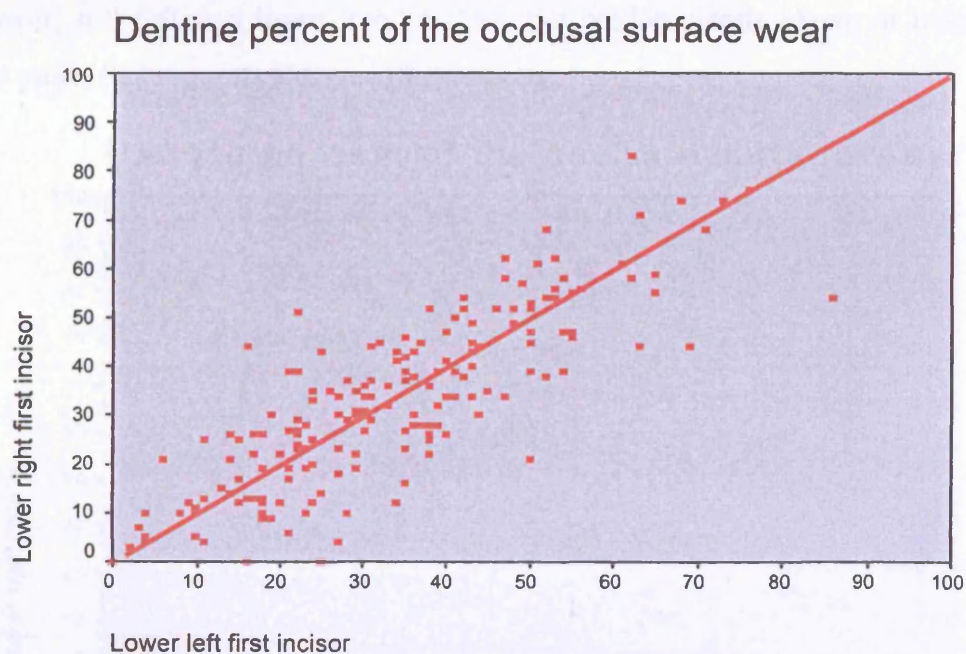


Figure 7.1: Scatter plot of the dentine percent of the lower right and left I1.

The diagonal line in Figure 7.1 represents absolute symmetry. The plotted point for any left-right pair in which the dentine percentages are identical would lie along this line. Figure 7.1 shows that, in general, the points for lower I1 are clustered quite closely around this ideal line. In addition, they do not fall particularly heavily above or below the



line in any part of the range. Altogether, this suggests that the dentine percentages are relatively symmetrical for this I1.

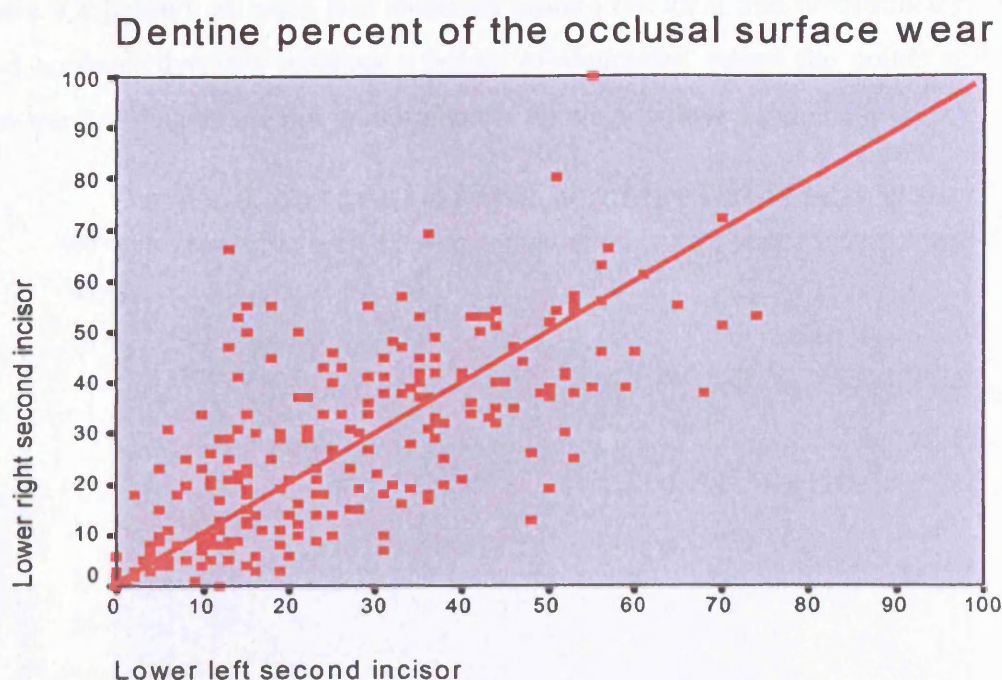


Figure 7.2: Scatter plot of the dentine percent of the lower right and left I2.

The points representing left-right pairs of lower I2 (Figure 7.2) are somewhat less strongly clustered, around the idealised diagonal line of symmetry, than I1. They do, however, still follow a linear trend and are not predominantly above or below the line. Once more, this suggests a degree of symmetry.

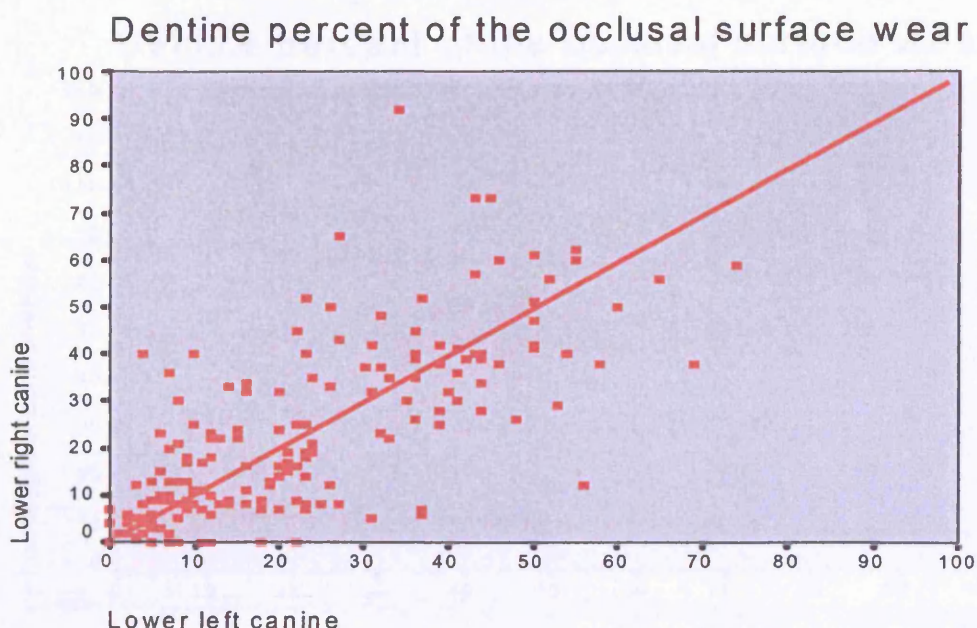


Figure 7.3: Scatter plot of the dentine percent for the lower right and left C.

In the scatter plot for the left-right C pairs (Figure 7.3), the scatters of points are not as closely clustered around to the absolute symmetry line as I1 and I2 pairs. The points



however still follow a linear trend and are not predominately above or below the ideal line, but suggest a degree of symmetry for this tooth type. The left-right pairs for P1 (Figure 7.4 below) are even less clustered around the ideal line of symmetry. It can be stated however that this suggests a degree of symmetry, where the points still follow a linear trend and again are not predominantly above or below the line.

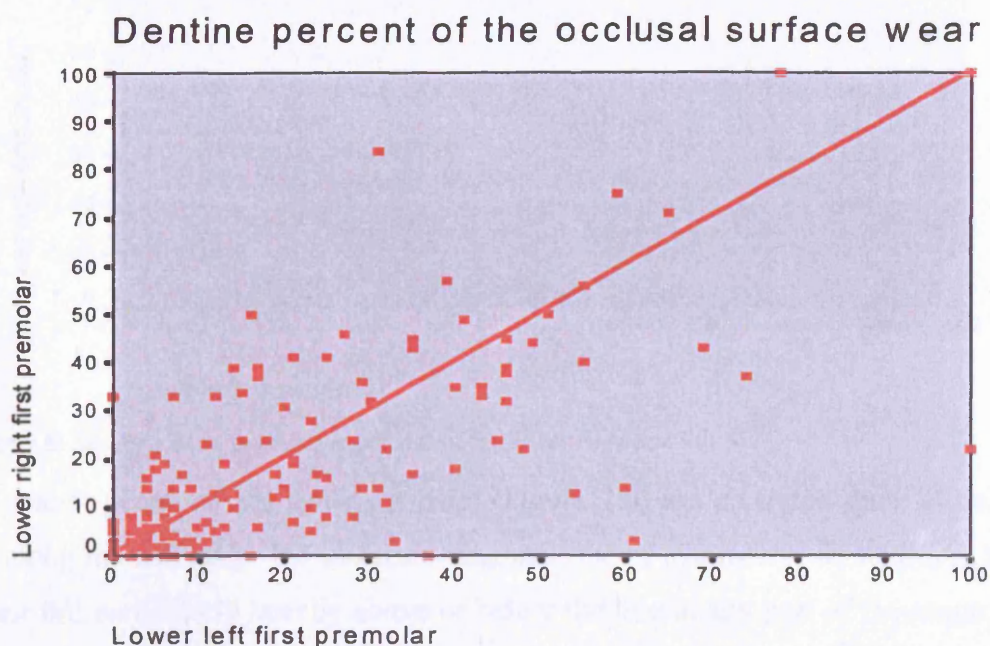


Figure 7.4: Scatter plot of the dentine percent of the lower right and left P1.

The same is true for P2 left-right pairs (Figure 7.5) where the points are not strongly clustered around the idealized line of symmetry.

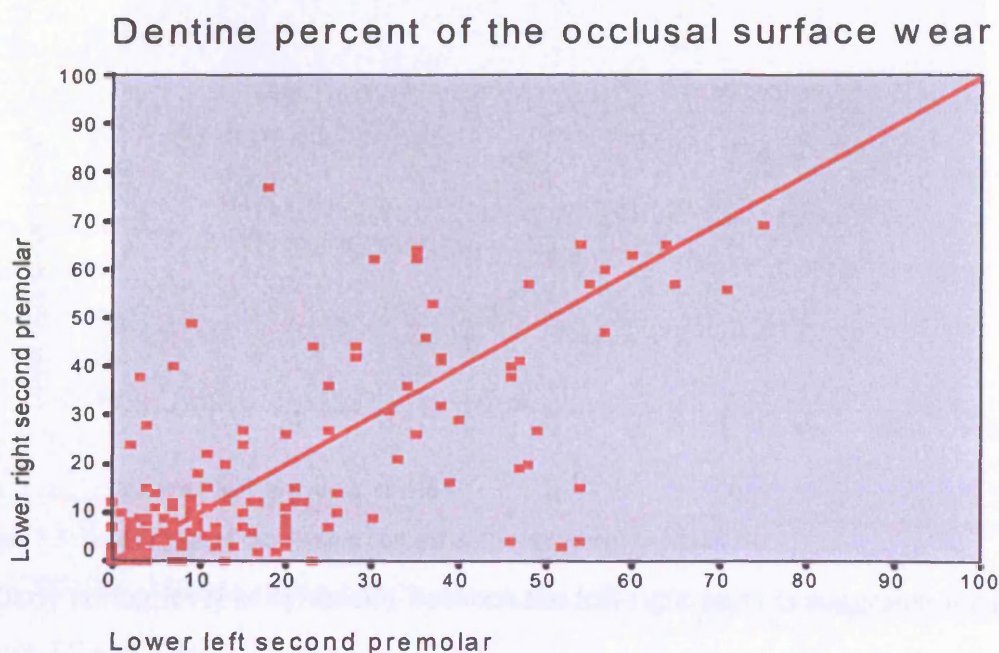


Figure 7.5: Scatter plot of the dentine percent of the lower right and left P2.

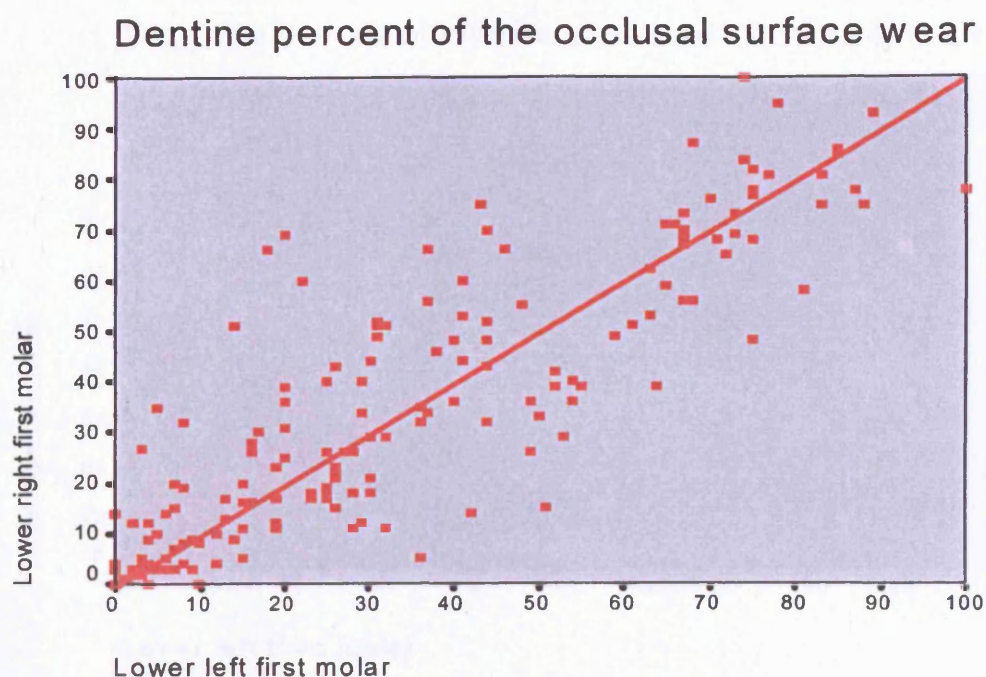


Figure 7.6: Scatter plot of the dentine percent of the lower right and left M1.

The scatter points of M1 left-right pairs (Figure 7.6) are clustered quite closely around and along the full range the idealized diagonal line of symmetry. In addition, the points do not fall particularly heavily above or below the line in any part of the range. Like I1, this suggests a relatively strong degree of symmetry.

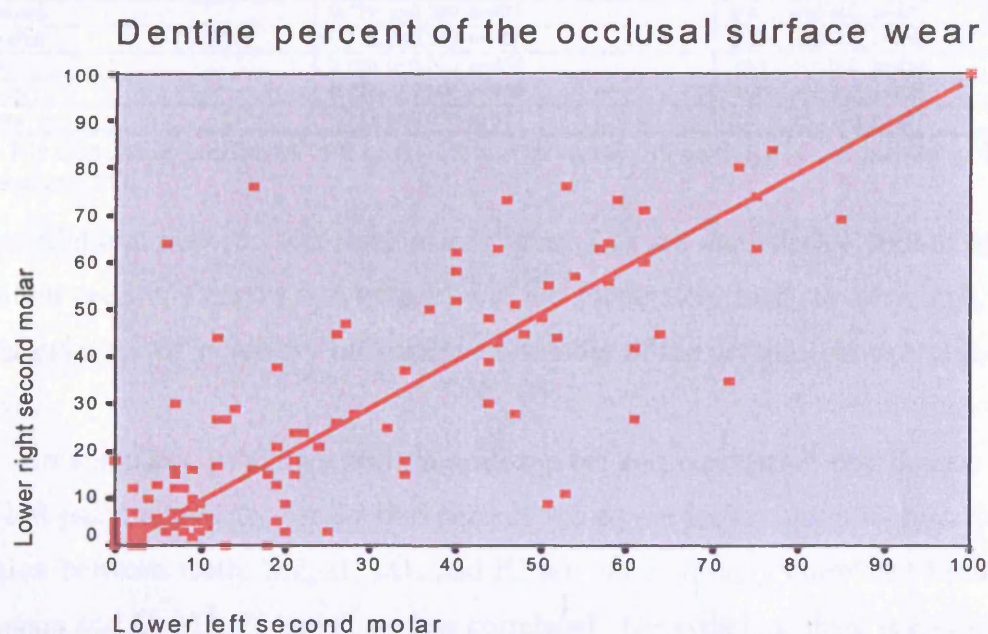


Figure 7.7: Scatter plot of the dentine percent of the lower right and left M2.

Similarly strong level of symmetry between the left-right pairs is suggested for M2 pairs (Figure 7.7 and 7.8).



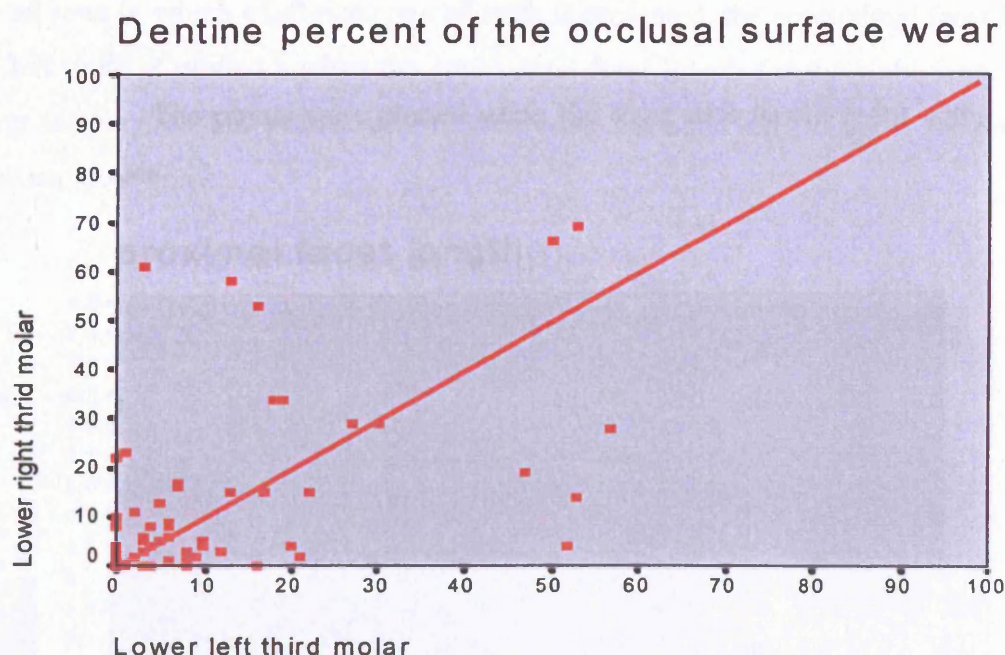


Figure 7.8: Scatter plot of the dentine percent of the lower right and left M3.

The scatter points of M3 left-right pairs (Figure 7.8) are not as closely clustered around the idealized line of symmetry as some of the other tooth types.

**Correlations coefficient tests of the dentine percent from the lower left-right pairs**

LEFT-RIGHT PAIRS	KENDALL TAU B	SPEARMAN RHO
1 <sup>st</sup> incisors	0.777, $p \leq 0.000$ , $n=351$	0.899, $p \leq 0.000$ , $n=351$
2 <sup>nd</sup> incisors	0.719, $p \leq 0.000$ , $n=403$	0.850, $p \leq 0.000$ , $n=403$
Cs	0.753, $p \leq 0.000$ , $n=488$	0.899, $p \leq 0.000$ , $n=488$
1 <sup>st</sup> premolars	0.739, $p \leq 0.000$ , $n=471$	0.885, $p \leq 0.000$ , $n=471$
2 <sup>nd</sup> premolar	0.756, $p \leq 0.000$ , $n=486$	0.886, $p \leq 0.000$ , $n=486$
1 <sup>st</sup> molars	0.760, $p \leq 0.000$ , $n=454$	0.895, $p \leq 0.000$ , $n=454$
2 <sup>nd</sup> molars	0.772, $p \leq 0.000$ , $n=439$	0.900, $p \leq 0.000$ , $n=439$
3 <sup>rd</sup> molars	0.733, $p \leq 0.000$ , $n=347$	0.838, $p \leq 0.000$ , $n=347$

Table 7.1: Correlation coefficient tests of the dentine percent for all tooth types. ( $n$ = number of individuals used, and  $p \leq 0.05$ ).

All correlations between left-right pairs (Table 7.1) are statistically significant by the definition used in Chapter 6, Methods, and are moderately high, to very high. This is further evidence of symmetry between the two sides of the dentition in values for dentine percent.

In summary, as shown both in scatter plots and correlation coefficients between right-left pairs, symmetry for dentine percent values are high. There is, however, some variation between teeth: M2, I1, M1, and P2 are more strongly correlated between left-right pairs and I2, M3, P1 and C are less correlated. Nevertheless, there is no evidence of a directional asymmetry which would prevent the use of one side to represent the dentition as a whole. It was therefore decided that the lower right quadrant would be used to represent the dentition as a whole.

### Approximal facet length

For all jaws in which a left-right pair of teeth is presented, the approximal facet length for the left tooth is plotted against the approximal facet length for the right tooth, for each lower tooth type. The points were plotted using the same axis to allow for comparison between tooth types.

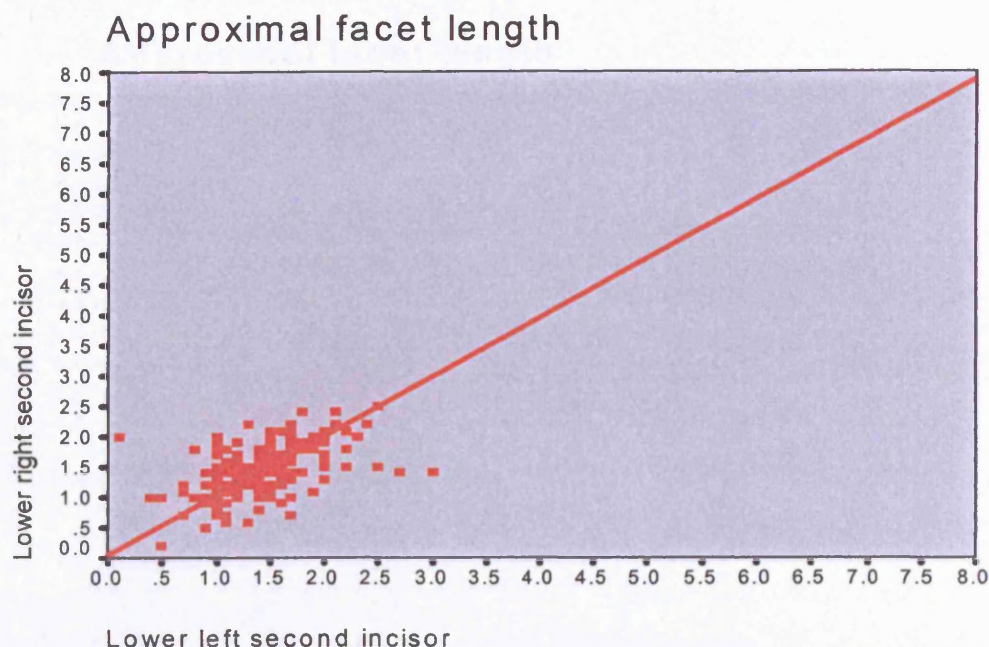


Figure 7.9: Scatter points of the approximal facet length of the lower right I2 plotted against the lower left I2.

As in the previous scatter plots of the dentine percent, the line represents absolute symmetry between the left-right pairs. Figure 7.9 of I2 left-right pairs shows the symmetry of the points are somewhat different.

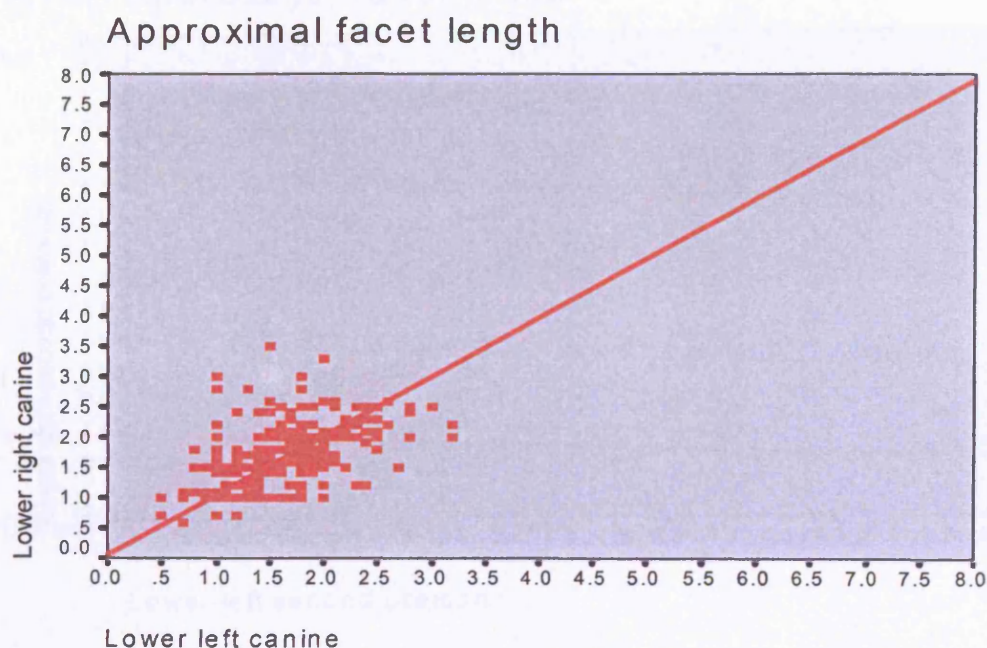


Figure 7.10: Scatter points of the approximal facet length of the lower right C plotted against the lower left C.



In scatter plot Figure 7.10 left-right pairs of C shows similar level of symmetry as the I2 above. Unlike the dentine percent plots, there are relatively few low values for both I1 and C left-right pairs. Nevertheless, they are still equally clustered above and below the line.

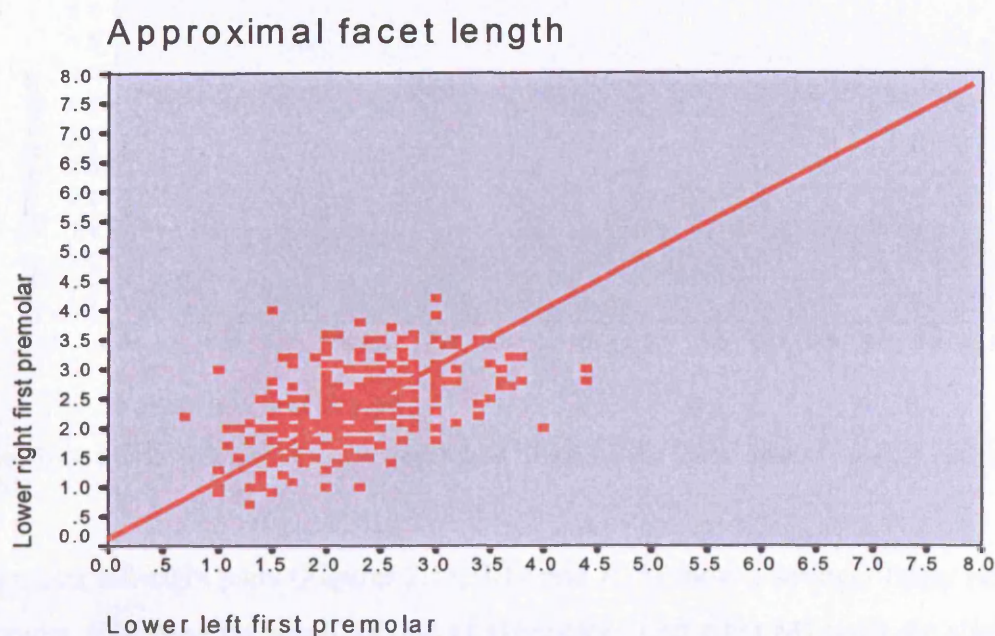


Figure 7.11: Scatter points of the approximal facet length for the lower right P1 plotted against the left P1.

As with I2 and C, the premolar left-right pairs (Figures 7.11 and 7.12) are clustered along the ideal *Symmetry* line, but not spread out along the line. This suggests a degree of symmetry but not as strong as in the dentine percent.

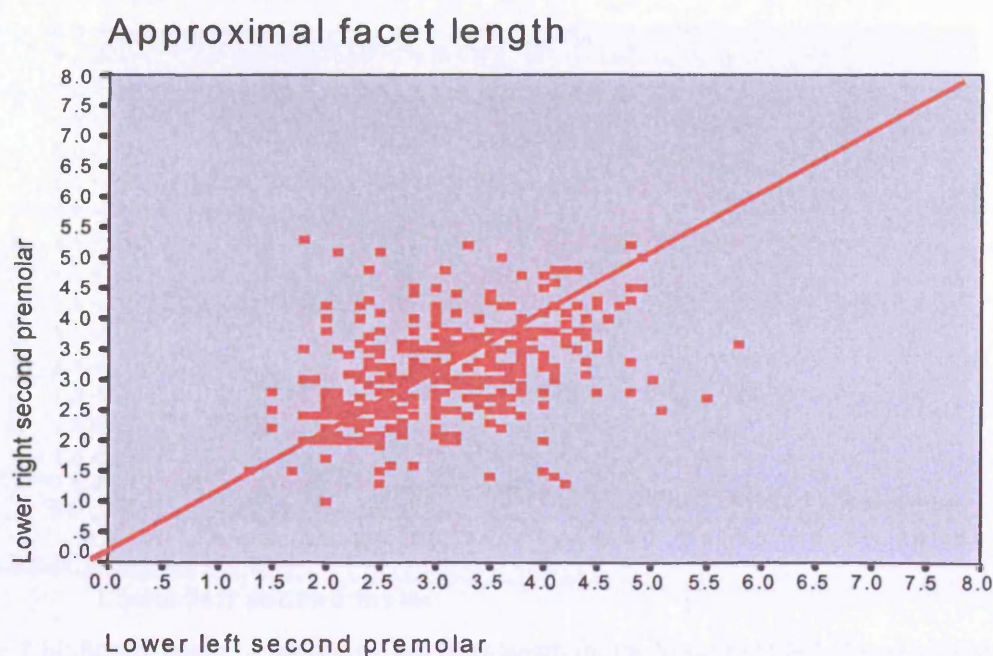


Figure 7.12: Scatter points of the approximal fact length for the lower right and left P2.

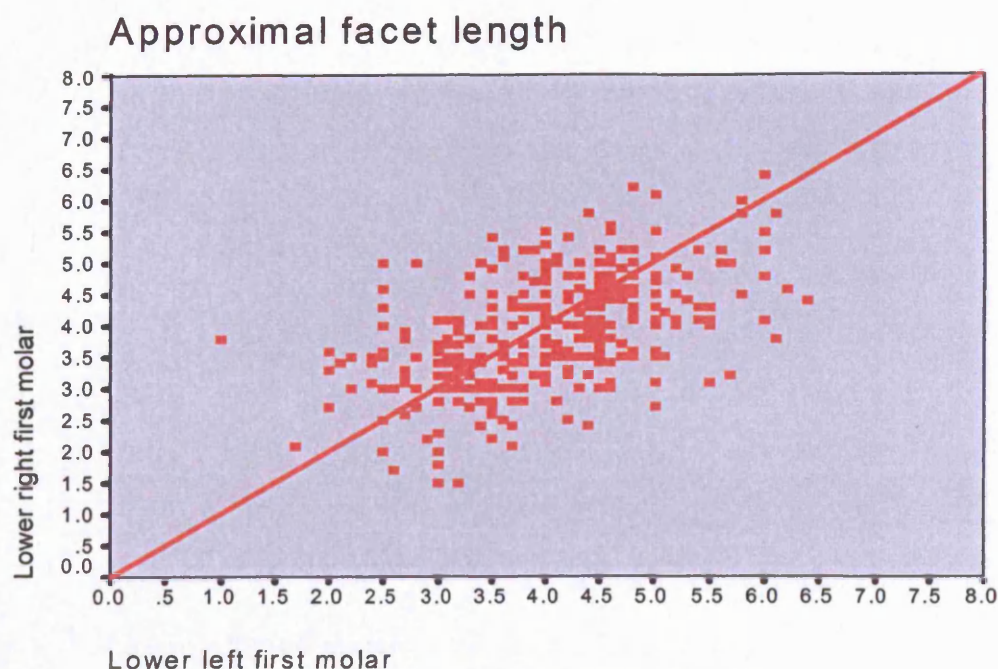


Figure 7.13: Scatter points of the approximal facet length for the lower right M1 plotted against the lower left M1.

The molar left-right pairs (Figures 7.13, 7.14 and 7.15) show a stronger linear relationship of points, following the idealized line of symmetry. Left-right M1 pairs are slightly more clustered along the idealized line than the points for the anterior teeth. The idealized line of symmetry also bisects the cluster with equal amount of points above and below the line.

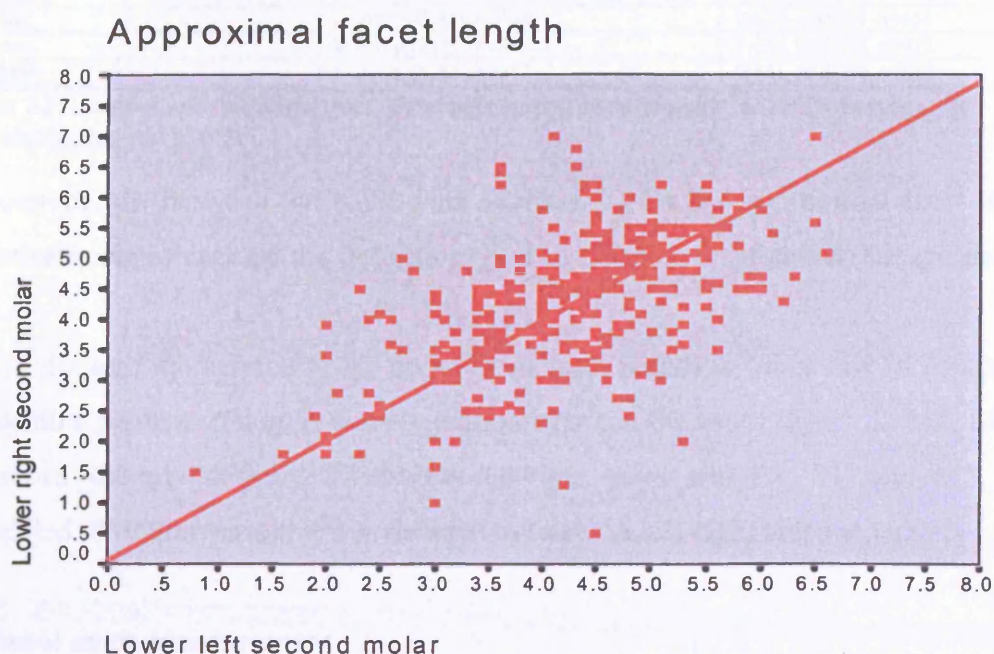


Figure 7.14: Scatter points of the approximal facet length for the lower right M2 plotted against the lower left M2.



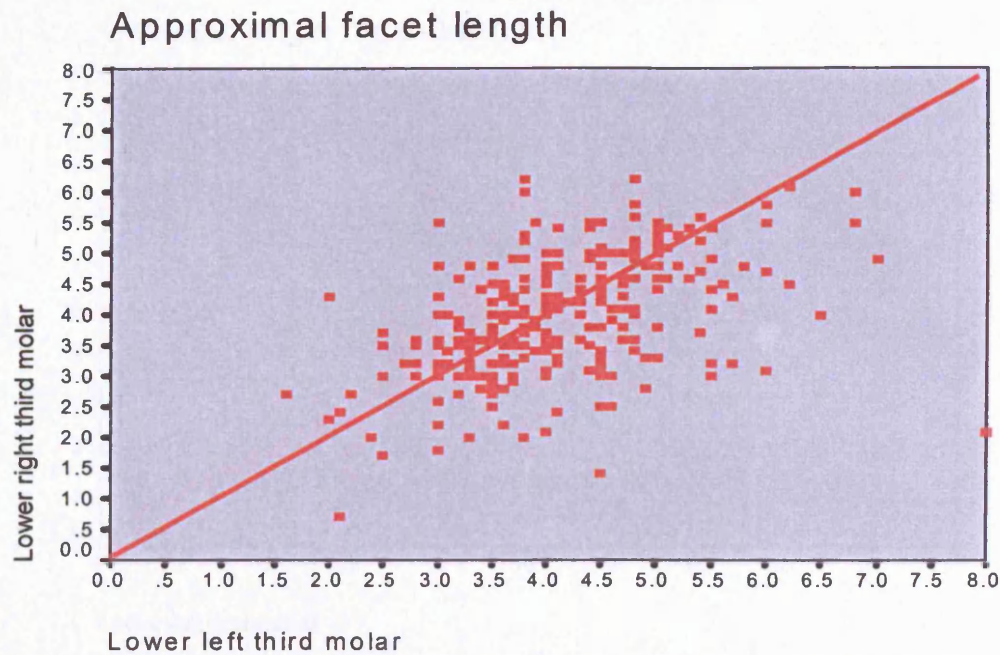


Figure 7.15: Scatter points of the approximal facet length for the lower right M3 plotted against the lower left M3.

The left-right M3 pairs (Figure 7.15) are much like the previous molar scatter points. The points are again in a more linear trend along the idealized line of symmetry with equal points above and below the line.

**Correlations coefficient tests of the approximal facet length from the lower left-right pairs**

LEFT-RIGHT PAIRS	KENDALL TAU B	SPEARMAN RHO
2 <sup>nd</sup> incisors	0.580, $p \leq 0.000$ , $n=403$	0.696, $p \leq 0.000$ , $n=403$
Cs	0.483, $p \leq 0.000$ , $n=488$	0.590, $p \leq 0.000$ , $n=488$
1 <sup>st</sup> premolars	0.438, $p \leq 0.000$ , $n=471$	0.545, $p \leq 0.000$ , $n=471$
2 <sup>nd</sup> premolar	0.423, $p \leq 0.000$ , $n=486$	0.560, $p \leq 0.000$ , $n=486$
1 <sup>st</sup> molars	0.465, $p \leq 0.000$ , $n=454$	0.620, $p \leq 0.000$ , $n=454$
2 <sup>nd</sup> molars	0.471, $p \leq 0.000$ , $n=439$	0.633, $p \leq 0.000$ , $n=439$
3 <sup>rd</sup> molars	0.396, $p \leq 0.000$ , $n=347$	0.531, $p \leq 0.000$ , $n=347$

Table 7.2: Correlation coefficient tests of the approximal facet lengths for all tooth types. ( $n$ = number of individuals used and  $p \leq 0.05$ ).

All correlations between left-right pairs (Table 7.2) for the approximal facet length are statistically significant by the definition used in Chapter 6, Methods, but are moderately low.

To sum up, symmetry for approximal facet length is fairly low in comparison to the dentine percent. There is some variation between the tooth types: I2, M2, M1, and C are more strongly correlated between left-right pairs and P2, P1, and M3, are less correlated. For this reason, it was decided to treat the left-right sides separately.

### Occlusal angle measurement

For all jaws in which a left-right pair of molars was presented, the occlusal angle measurement for the left tooth has been plotted below against the occlusal angle measurement for the right tooth, for each lower tooth type.

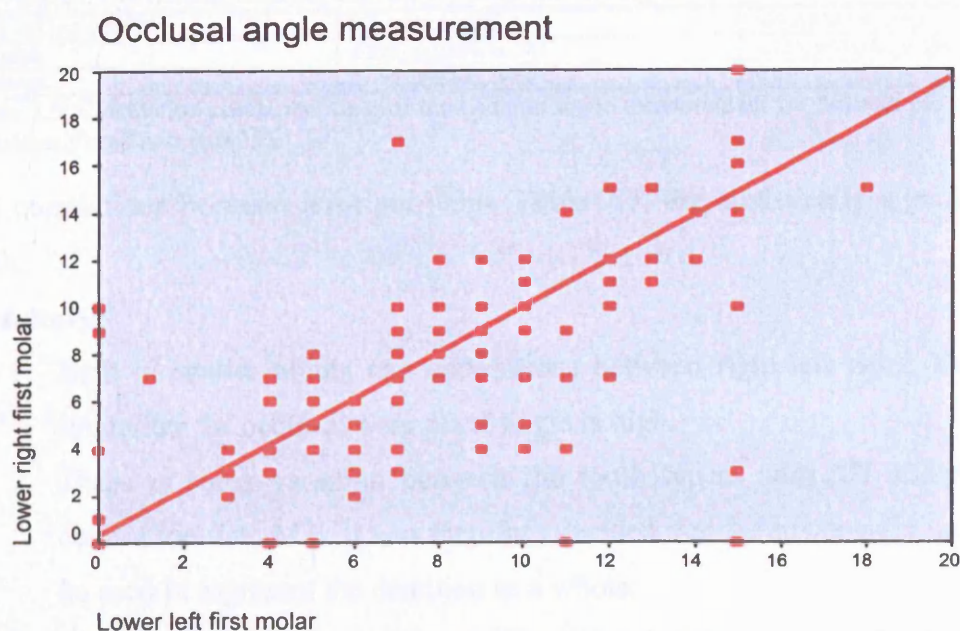


Figure 7.16: Scatter plot of the occlusal angle measurements for the lower right M1 plotted against the lower left M1s.

Figure 7.16 shows that the points for lower left-right M1 pairs are clustered quite evenly around the ideal line of symmetry. In addition, they do not fall particularly heavily above or below the line in any part of the range. Altogether, this suggests that the occlusal angle measurements are relatively symmetrical for this tooth type.

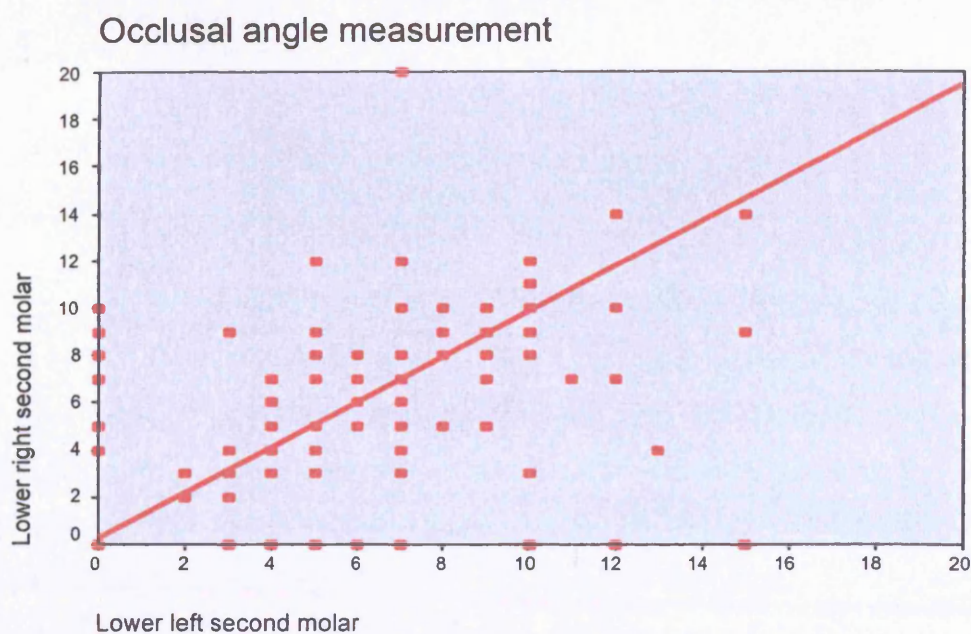


Figure 7.17: Scatter points of the occlusal angle measurement for the lower right M2 plotted against the lower left M2.

The same is true for M2 left-right pairs (Figure 7.17) but the relationship is less strongly developed.



**Correlation Coefficient tests occlusal angles from the left-right sides**

LEFT-RIGHT PAIRS	KENDALL TAU B	SPEARMAN RHO
1 <sup>st</sup> molars	0.821, $p \leq 0.000$ , $n=382$	.0885, $p \leq 0.000$ , $n=454$
2 <sup>nd</sup> molars	0.795, $p \leq 0.000$ , $n=369$	0.849, $p \leq 0.000$ , $n=363$

Table 7.3: Correlation coefficient tests of the occlusal angle measurement for M1 and M2. ( $n$ = number of individuals used and  $p \leq 0.05$ ).

All correlations between left-right pairs (Table 7.3) are statistically significant and are high.

**Summary:**

1. Both in scatter points and correlations between right-left pairs, shows that the symmetry for occlusal wear plane angle is high.
2. There is some variation between the tooth types: with M1 showing a higher correlation than M2. It was therefore decided that the lower right quadrant would be used to represent the dentition as a whole.
3. Overall the dentine percent and the occlusal wear plane angle show the results from the lower right teeth.
4. The approximal facet shows the results from both the lower right and left sides.
5. Similar results were found for the upper right-left sides. *occlusal angles*

### 7.1.B An increase of wear for independent age indicators

This section examines increasing wear (occlusal, approximal and occlusal angle changes) in relation to independent age indicators. A tooth from each section of the jaw (I1, P1, M1 and M2 for occlusal angle only) has been selected for the box plots and Kruskal-Wallis tests to assess the affects of age within the different behavioural groups. The independent age groups are defined in Methods chapter 6.

#### 1. Full collection independent age indicators

##### Dentine percent

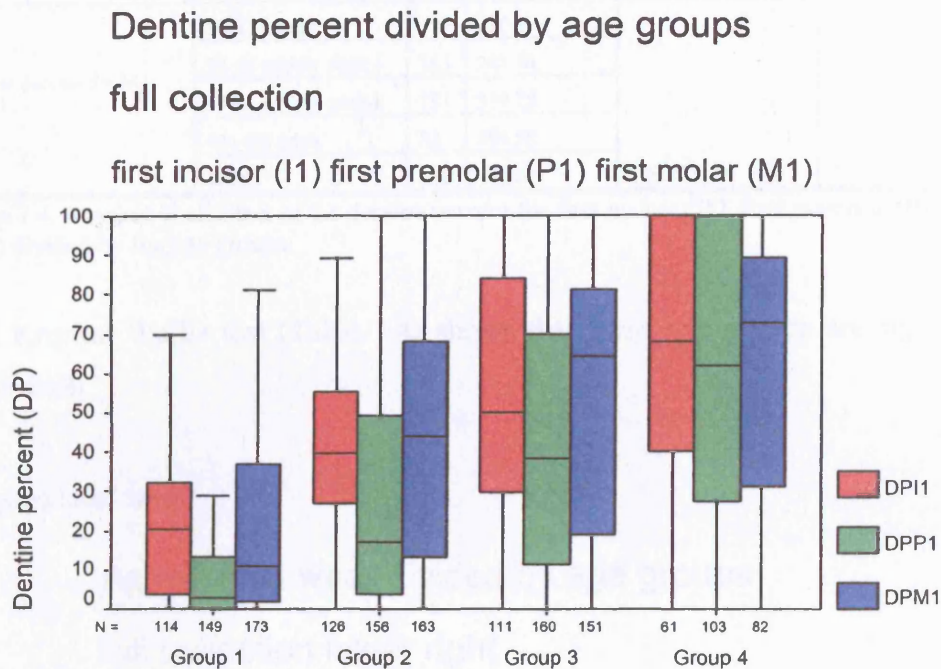


Figure 7.18: Box plot of the dentine percent (DP) of first incisor (I1), first premolar (P1) and first molar (M1) of the full collection divided by the age groups. (Group 1= young 20-25 years, Group 2=middle adult 1 25-35 years, Group 3= middle adult 2 35-45 years and Group 4= old adult 45+ years).

In Figure 7.18 the values for the medians, upper and lower quartiles increase from age groups 1 to 4, but there is extensive overlap between the age groups and between the teeth. In general the interquartile range increases from age groups 1 to 4, so that the overlap between tooth types becomes more marked. For each age group the medians for I1 and M1 are higher than P1 median. To sum up, the median dentine percent increases with age, but there is considerable variation within each age group.

Kruskal-Wallis test Dentine percent

	AGE	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Dentine percent I1	20-25 young	114	122.07	94.297	3	0.000
	25-35 middle adult 1	126	211.99			
	35-45 middle adult 2	111	244.61			
	45+ old adult	61	283.60			
	Total	412				
Dentine percent for P1	20-25 young	149	170.14	140.529	3	0.000
	25-35 middle adult 1	156	266.06			
	35-45 middle adult 2	160	335.82			
	45+ old adult	103	398.16			
	Total	568				
Dentine percent for M1	20-25 young	173	190.07	100.213	3	0.000
	25-35 middle adult 1	163	288.96			
	35-45 middle adult 2	151	339.75			
	45+ old adult	82	376.58			
	Total	569	190.07			

Table 7.4: Kruskal-Wallis test of the dentine percent for first incisor (I1), first premolar (P1) and first molar (M1) divided by the age groups.

The Kruskal-Wallis test (Table 7.4) shows that these age groups are significant for all three teeth.

### Approximal wear

#### Approximal wear divided by age groups

#### full collection lower right

#### first incisor (I1), first premolar (P1), first molar (M1)

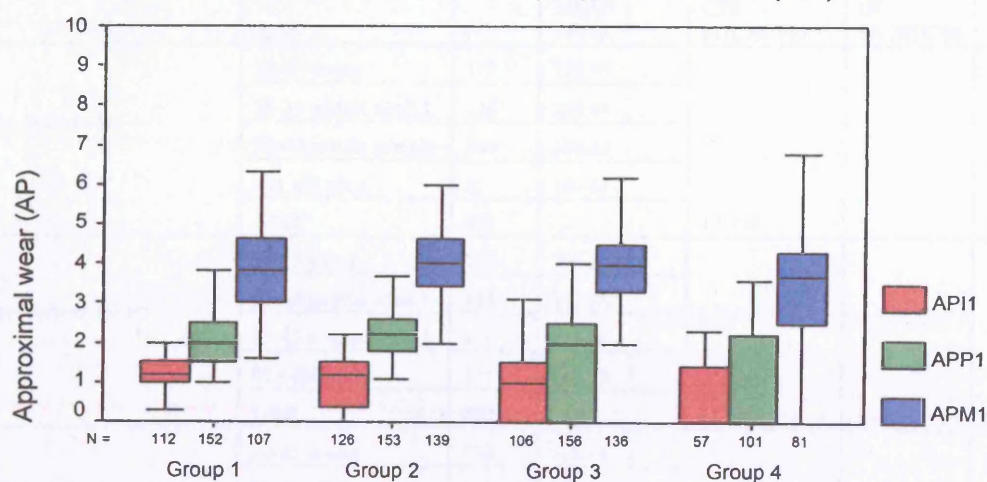


Figure 7.19: Box plot of the approximal wear (AP) lower right of first incisor (I1), first premolar (P1) and first molar (M1) of the full collection divided by the age groups. (Group 1= young 20-25 years, Group 2=middle adult 1 25-35 years, Group 3= middle adult 2 35-45 years and Group 4= old adult 45+ years).



## Approximal wear divided by age groups

full collection lower left

first incisor (I1) first premolar (P1) first molar (M1)

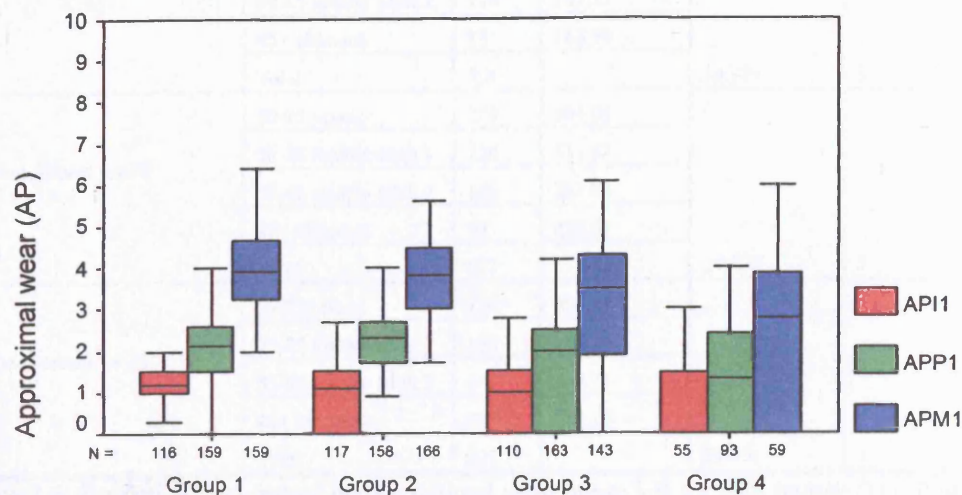


Figure 7.20: Box plot of the approximal wear (AP) lower left of first incisor (I1), first premolar (P1) and first molar (M1) of the full collection divided by the age groups. (Group 1= young 20-25 years, Group 2=middle adult 1 25-35 years, Group 3= middle adult 2 35-45 years and Group 4= old adult 45+ years).

In Figure 7.19 and 7.20 there are strong differences in the medians lengths of the approximal wear facets. This is presumably related to the different sizes of tooth crowns. There is no strong trend with increasing age, but all three teeth show a decrease in the median. The interquartile ranges also become larger and overlap more with the increase of age.

### Kruskal-Wallis test Approximal wear right

	AGE	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Dentine percent I1	20-25 young	112	228.99	17.850	3	0.000
	25-35 middle adult 1	126	210.44			
	35-45 middle adult 2	106	182.23			
	45+ old adult	57	160.04			
	Total	401				
Dentine percent for P1	20-25 young	152	296.29	31.035	3	0.000
	25-35 middle adult 1	153	322.26			
	35-45 middle adult 2	156	272.78			
	45+ old adult	101	210.97			
	Total	562				
Dentine percent for M1	20-25 young	170	318.34	39.350	3	0.000
	25-35 middle adult 1	162	311.64			
	35-45 middle adult 2	148	253.29			
	45+ old adult	83	200.92			
	Total	563	228.99			

Table 7.5: Kruskal-Wallis test of the approximal wear lower right for first incisor (I1), first premolar (P1) and first molar (M1) divided by the age groups.

Kruskal-Wallis test Approximal wear lower left

	AGE	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Dentine percent I1	20-25 young	116	227.72	13.976	3	0.000
	25-35 middle adult 1	117	200.96			
	35-45 middle adult 2	110	185.25			
	45+ old adult	55	165.39			
	Total	398				
Dentine percent for P1	20-25 young	159	304.04	29.874	3	0.000
	25-35 middle adult 1	158	331.52			
	35-45 middle adult 2	163	261.68			
	45+ old adult	93	226.61			
	Total	573				
Dentine percent for M1	20-25 young	159	304.53	33.001	3	0.000
	25-35 middle adult 1	166	276.20			
	35-45 middle adult 2	143	237.71			
	45+ old adult	59	184.18			
	Total	527				

Table 7.6: Kruskal-Wallis test of the approximal wear lower left for first incisor (I1), first premolar (P1) and first molar (M1) divided by the age groups.

Despite the overlap of the interquartile and overall ranges, the Kruskal-Wallis test (Tables 7.5 and 7.6) indicates that the fall in median approximal wear facet length is statistically significant between the age groups.

### Occlusal wear plane angle

Occlusal wear plane angles divided by  
age groups full collection

first molar (M1) second molar (M2)

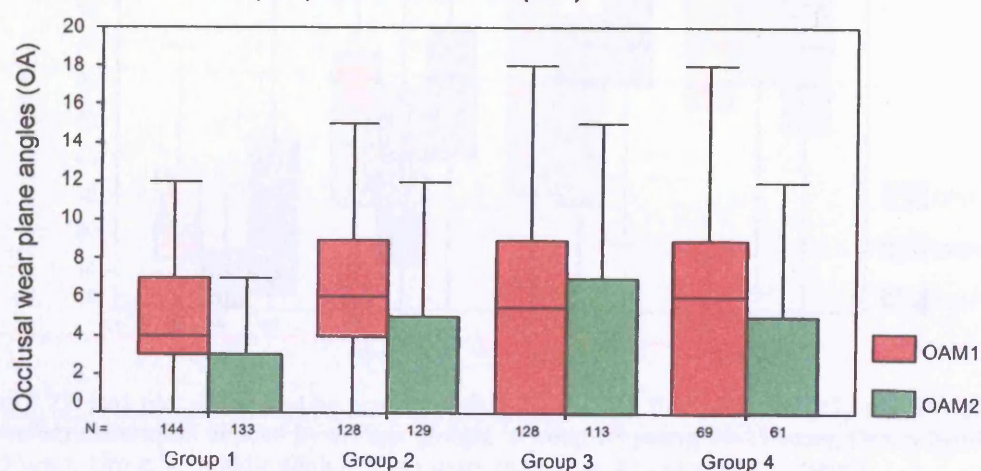


Figure 7.21: Box plot of the occlusal wear plane angle (OA) of first molar (M1) and second molar (M2) of the full collection divided by the age groups. (Group 1= young 20-25 years, Group 2= middle adult 1 25-35 years, Group 3= middle adult 2 35-45 years and Group 4= old adult 45+ years).



Figure 7.21 shows the interquartile ranges are smaller in age groups 1 and 2 and larger in age groups 3 and 4. The median wear plane for M1 is higher than M2. There is also a slight trend with age, with the two middle age groups having higher values than the youngest and oldest. The Kruskal-Wallis test (Table 7.7) suggests that these differences are statistically significant.

**Kruskal-Wallis test Occlusal wear plane angle**

	AGE	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Dentine percent M1	20-25 young	144	208.09	10.986	3	0.012
	25-35 middle adult 1	128	258.30			
	35-45 middle adult 2	128	246.77			
	45+ old adult	69	226.10			
	Total	469				
Dentine percent for M2	20-25 young	133	187.55	17.188	3	0.001
	25-35 middle adult 1	129	226.53			
	35-45 middle adult 2	113	243.56			
	45+ old adult	61	222.58			
	Total	436	208.09			

Table 7.7: Kruskal-Wallis test of the occlusal wear plane angle for first molar (M1) and second molar (M2) divided by the age groups.

## 2. Non-agriculturalists independent age indicators

### Dentine percent

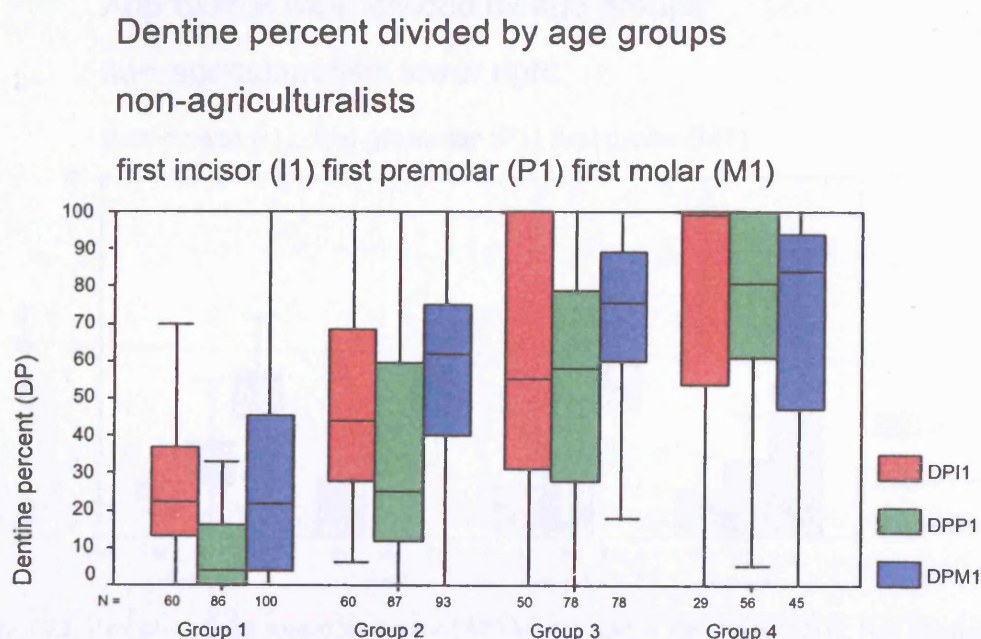


Figure 7.22: Box plot of the dentine percent of first incisor (I1), first premolar (P1) and first molar (M1) of the non-agriculturalists divided by the age groups. (Group 1= young 20-25 years, Group 2=middle adult 1 25-35 years, Group 3= middle adult 2 35-45 years and Group 4= old adult 45+ years).

In Figure 7.22, which shows the non-agriculturalists on their own, the pattern of the differences between teeth is similar to that which is shown in Figure 7.18 (full collection).

There is however a much stronger increase in median dentine percent with age. This is shown by the Kruskal-Wallis (Table 7.8) test to be statistically highly significant.

**Kruskal-Wallis test Dentine percent**

	AGE	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Dentine percent I1	20-25 young	60	59.05	51.606	3	0.000
	25-35 middle adult 1	60	105.18			
	35-45 middle adult 2	50	118.89			
	45+ old adult	29	141.45			
	Total	199				
Dentine percent for P1	20-25 young	86	83.31	106.724	3	0.000
	25-35 middle adult 1	87	145.53			
	35-45 middle adult 2	78	187.94			
	45+ old adult	56	228.44			
	Total	307				
Dentine percent for M1	20-25 young	100	81.12	66.803	3	0.000
	25-35 middle adult 1	93	110.06			
	35-45 middle adult 2	78	136.09			
	45+ old adult	45	186.73			
	Total	316				

Table 7.8: Kruskal-Wallis test of the dentine percent for first incisor (I1), first premolar (P1) and first molar (M1) divided by the age groups.

### Approximal wear

Approximal wear divided by age groups

non-agriculturalists lower right

first incisor (I1), first premolar (P1) first molar (M1)

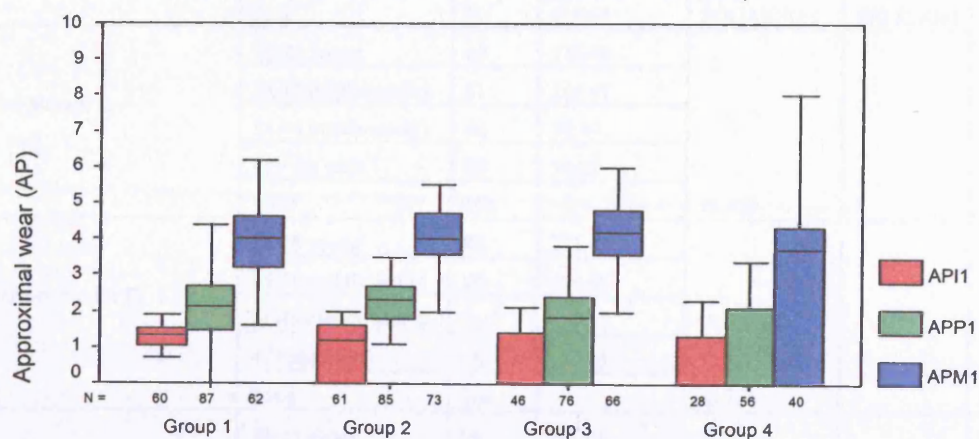


Figure 7.23: Box plot of the approximal wear (AP) lower right of first incisor (I1), first premolar (P1) and first molar (M1) of the non-agriculturalists divided by the age groups. (Group 1= young 20-25 years, Group 2=middle adult 1 25-35 years, Group 3= middle adult 2 35-45 years and Group 4= old adult 45+ years).



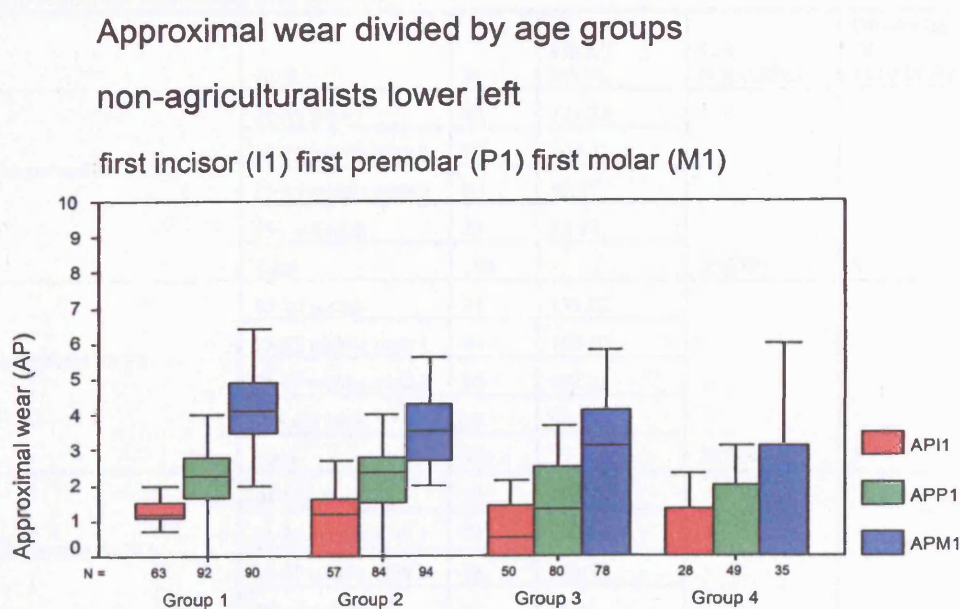


Figure 7.24: Box plot of the approximal wear (AP) lower left of first incisor (I1), first premolar (P1) and first molar (M1) of the non-agriculturalists divided by the age groups. (Group 1= young 20-25 years, Group 2=middle adult 1 25-35 years, Group 3= middle adult 2 35-45 years and Group 4= old adult 45+ years).

In Figure 7.23 and 7.24 the pattern of differences between teeth is very similar to that seen in Figure 7.19 and 7.20 (full collection). In I1 and M1 there is a decrease in the median approximal wear facet length with age, but P1 shows a rise into the second age group followed by a fall in approximal wear facet length. These trends are highly significant, as shown by the Kruskal-Wallis tests (Tables 7.9 and 7.10).

Kruskal-Wallis test Approximal wear lower right

	AGE	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Dentine percent I1	20-25 young	60	116.66	18.222	3	0.000
	25-35 middle adult 1	61	104.61			
	35-45 middle adult 2	46	79.49			
	45+ old adult	28	74.02			
	Total	195				
Dentine percent for P1	20-25 young	87	171.02	33.104	3	0.000
	25-35 middle adult 1	85	179.65			
	35-45 middle adult 2	76	137.37			
	45+ old adult	56	103.05			
	Total	304				
Dentine percent for M1	20-25 young	98	201.44	53.306	3	0.000
	25-35 middle adult 1	94	172.60			
	35-45 middle adult 2	79	122.77			
	45+ old adult	46	103.00			
	Total	317				

Table 7.9: Kruskal-Wallis test of the lower right approximal wear for first incisor (I1), first premolar (P1) and first molar (M1) divided by the age groups.



**Kruskal-Wallis test Approximal wear lower left**

	AGE	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Dentine percent I1	20-25 young	63	121.29	20.679	3	0.000
	25-35 middle adult 1	57	103.51			
	35-45 middle adult 2	50	82.07			
	45+ old adult	28	73.43			
	Total	198				
Dentine percent for P1	20-25 young	92	175.02	39.064	3	0.000
	25-35 middle adult 1	84	180.60			
	35-45 middle adult 2	80	132.31			
	45+ old adult	49	98.13			
	Total	305				
Dentine percent for M1	20-25 young	90	192.38	49.387	3	0.000
	25-35 middle adult 1	94	150.43			
	35-45 middle adult 2	78	126.70			
	45+ old adult	35	83.31			
	Total	297				

Table 7.10: Kruskal-Wallis test of the lower left approximal wear for first incisor (I1), first premolar (P1) and first molar (M1) divided by the age groups.

**Occlusal wear plane angles**

Occlusal wear plane angle divided by age

groups non-agriculturalists

first molar (M1) second molar (M2)

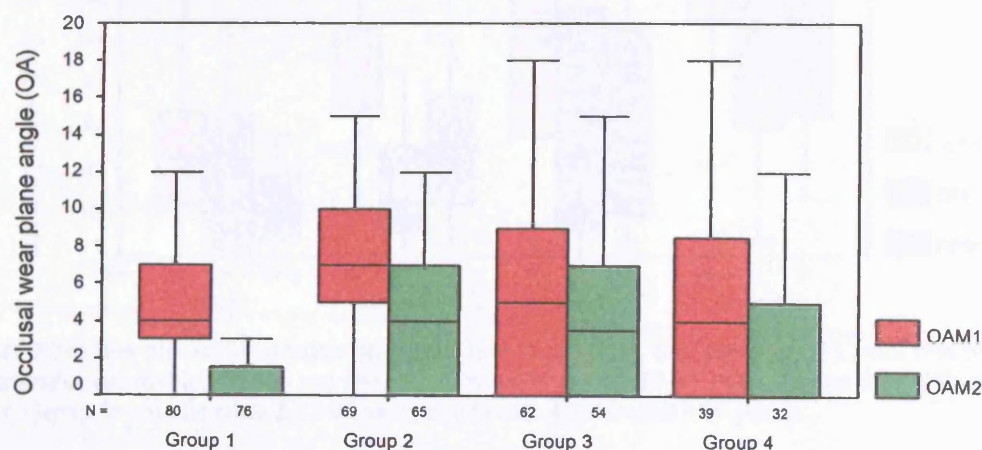


Figure 7.25: Box plot of the occlusal wear plane angle (OA) of first molar (M1) and second molar (M2) of the non-agriculturalists divided by the age groups. (Group 1= young 20-25 years, Group 2= middle adult 1 25-35 years, Group 3= middle adult 2 35-45 years and Group 4= old adult 45+ years).

In Figure 7.25 the pattern of changes to the occlusal wear plane angle follows the trend shown in Figure 7. 21 (full collection), in which the two middle age groups are higher values than the youngest and oldest groups. Once again this trend is shown to be significant according to the Kruskal-Wallis tests (Table 7.11).

Kruskal-Wallis test Occlusal wear plane angle

	AGE	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Dentine percent M1	20-25 young	80	113.33	15.513	3	0.001
	25-35 middle adult 1	69	153.40			
	35-45 middle adult 2	62	121.45			
	45+ old adult	39	107.54			
	Total	250				
Dentine percent for M2	20-25 young	76	91.06	17.619	3	0.001
	25-35 middle adult 1	65	128.38			
	35-45 middle adult 2	54	126.62			
	45+ old adult	32	117.98			
	Total	227				

Table 7.11: Kruskal-Wallis test of the occlusal wear plane angle for first molar (M1) and second molar (M2) divided by the age groups.

### 3. Transitionals

#### Dentine percent

#### Dentine percent divided by age groups

#### transitionals

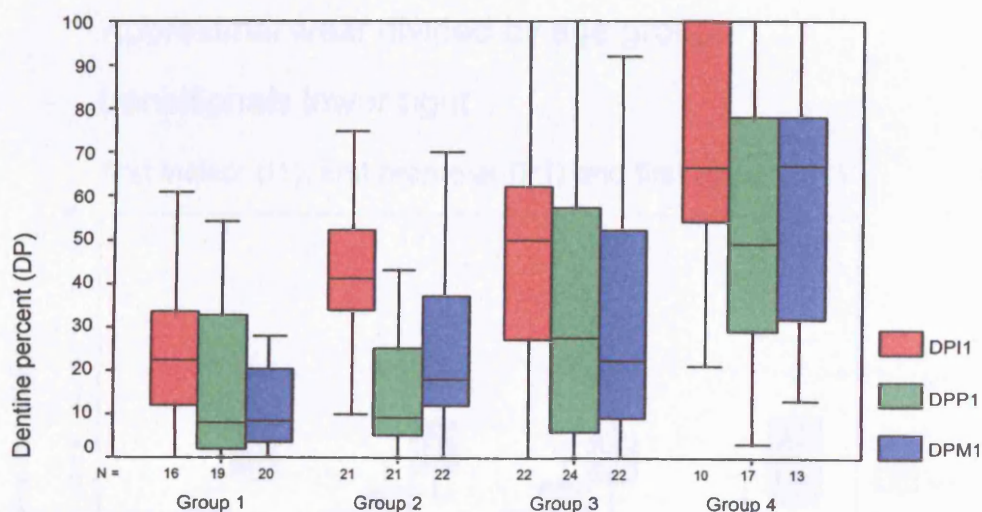


Figure 7.26: Box plot of the dentine percent of first incisor (I1), first premolar (P1) and first molar (M1) of the transitionals divided by the age groups. (Group 1= young 20-25 years, Group 2=middle adult 1 25-35 years, Group 3= middle adult 2 35-45 years and Group 4= old adult 45+ years).

In Figure 7.26 it can be seen that the transitionals follow a similar pattern as to the full collection (Figure 7.18). The rise of median dentine percent with age is therefore not as marked as in the non-agriculturalists (Figure 7.22). This is reflected in the Kruskal-Wallis test (Table 7.12) that is statistically significant but not highly significant, although this must partly be due to the smaller assemblage sizes.



Kruskal-Wallis test Dentine percent

	AGE	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Dentine percent I1	20-25 young	16	20.84	15.239	3	0.002
	25-35 middle adult 1	21	34.98			
	35-45 middle adult 2	22	37.80			
	45+ old adult	10	51.55			
	Total	69				
Dentine percent for P1	20-25 young	19	31.11	13.549	3	0.004
	25-35 middle adult 1	21	34.10			
	35-45 middle adult 2	24	43.38			
	45+ old adult	17	57.24			
	Total	81				
Dentine percent for M1	20-25 young	20	30.13	12.942	3	0.005
	25-35 middle adult 1	22	30.64			
	35-45 middle adult 2	22	40.81			
	45+ old adult	13	52.45			
	Total	77				

Table 7.12: Kruskal-Wallis test of the dentine percent for first incisor (I1), first premolar (P1) and first molar (M1) divided by the age groups.

### Approximal wear

#### Approximal wear divided by age groups

transitionals lower right

first incisor (I1), first premolar (P1) and first molar (M1)

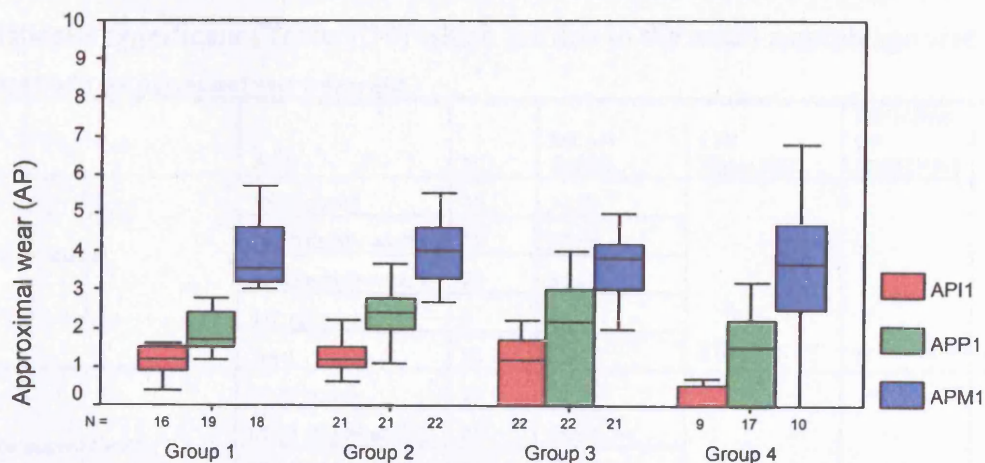


Figure 7.27: Box plot of the approximal wear (AP) lower right of first incisor (I1), first premolar (P1) and first molar (M1) of the transitionals divided by the age groups. (Group 1= young 20-25 years, Group 2=middle adult 1 25-35 years, Group 3= middle adult 2 35-45 years and Group 4= old adult 45+ years).

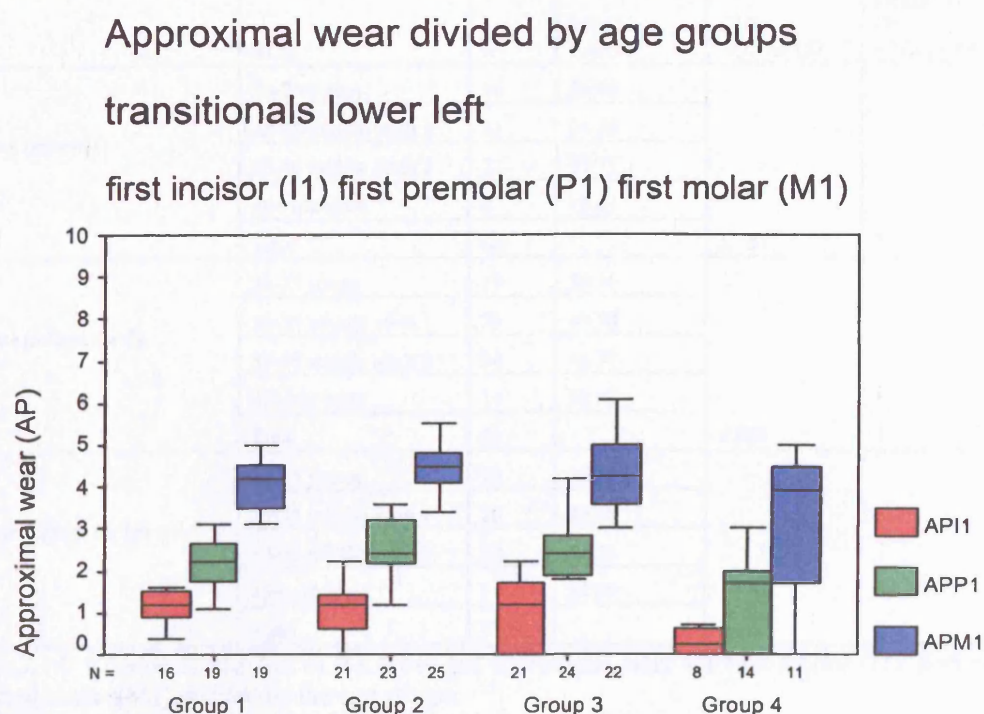


Figure 7.28: Box plot of the approximal wear (AP) lower left of first incisor (I1), first premolar (P1) and first molar (M1) of the transitionals divided by the age groups. (Group 1= young 20-25 years, Group 2=middle adult 1 25-35 years, Group 3= middle adult 2 35-45 years and Group 4= old adult 45+ years).

In Figures 7.27 and 7.28 it is apparent that the age trend of median approximal wear facet length is less marked than seen in the non-agriculturalists (Figures 7.23 and 7.24) and is thus closer to the full collection (Figures 7.19 and 7.20). The differences however are not statistically significant (Table 7.13) which are due to the small assemblage size.

**Kruskal-Wallis test Approximal wear lower right**

	AGE	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Dentine percent I1	20-25 young	16	37.59	6.933	3	0.074
	25-35 middle adult 1	21	37.88			
	35-45 middle adult 2	22	35.45			
	45+ old adult	9	18.78			
	Total	68				
Dentine percent for P1	20-25 young	19	37.50	7.013	3	0.071
	25-35 middle adult 1	21	48.62			
	35-45 middle adult 2	22	42.05			
	45+ old adult	17	29.50			
	Total	79				
Dentine percent for M1	20-25 young	21	40.71	7.709	3	0.065
	25-35 middle adult 1	22	45.50			
	35-45 middle adult 2	20	39.17			
	45+ old adult	13	22.04			
	Total	76				

Table 7.13: Kruskal-Wallis test of the lower right approximal wear for first incisor (I1), first premolar (P1) and first molar (M1) divided by the age groups.

**Kruskal-Wallis test Approximal wear lower left**



	AGE	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Dentine percent I1	20-25 young	16	36.66	5.387	3	0.146
	25-35 middle adult 1	21	34.36			
	35-45 middle adult 2	21	35.71			
	45+ old adult	8	19.13			
	Total	66				
Dentine percent for P1	20-25 young	19	38.16	4.886	3	0.202
	25-35 middle adult 1	23	49.50			
	35-45 middle adult 2	24	42.79			
	45+ old adult	14	28.68			
	Total	80				
Dentine percent for M1	20-25 young	19	34.26	4.526	3	0.210
	25-35 middle adult 1	25	44.68			
	35-45 middle adult 2	22	41.20			
	45+ old adult	11	29.86			
	Total	77				

Table 7.14: Kruskal-Wallis test of the lower left approximal wear for first incisor (I1), first premolar (P1) and first molar (M1) divided by the age groups.

### Occlusal wear plane angles

Occlusal wear plane angle divided by age

groups transitionals

first molar (M1) second molar (M2)

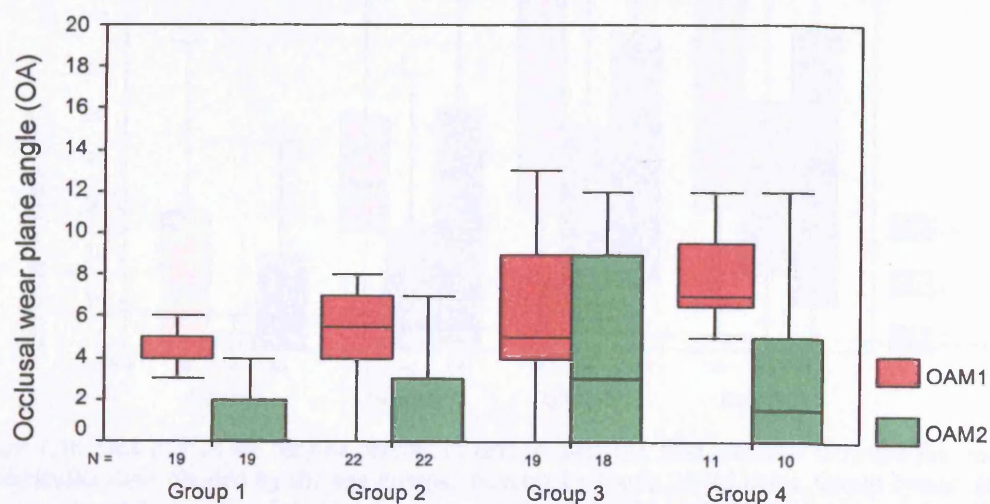


Figure 7.29: Box plot of the occlusal wear plane angle (OA) of first molar (M1) and second molar (M2) of the transitionals divided by the age groups. (Group 1= young 20-25 years, Group 2= middle adult 1 25-35 years, Group 3= middle adult 2 35-45 years and Group 4= old adult 45+ years).

Figure 7.29 shows that, for the transitionals, the occlusal wear plane angle increases with age group. This difference is significant for M1 but not M2 (Table 7.15).

Kruskal-Wallis test Occlusal wear plane angle

	AGE	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Dentine percent M1	20-25 young	19	23.89	13.323	3	0.004
	25-35 middle adult 1	22	35.84			
	35-45 middle adult 2	19	39.61			
	45+ old adult	11	51.00			
	Total	71				
Dentine percent for M2	20-25 young	19	30.24	6.827	3	0.078
	25-35 middle adult 1	22	30.68			
	35-45 middle adult 2	18	42.64			
	45+ old adult	10	39.80			
	Total	69				

Table 7.15:Kruskal-Wallis test of the occlusal wear plane angle for first molar (M1) and second molar (M2) divided by the age groups.

#### 4. Agriculturalists

##### Dentine percent

##### Dentine percent divided by age groups

##### agriculturalists

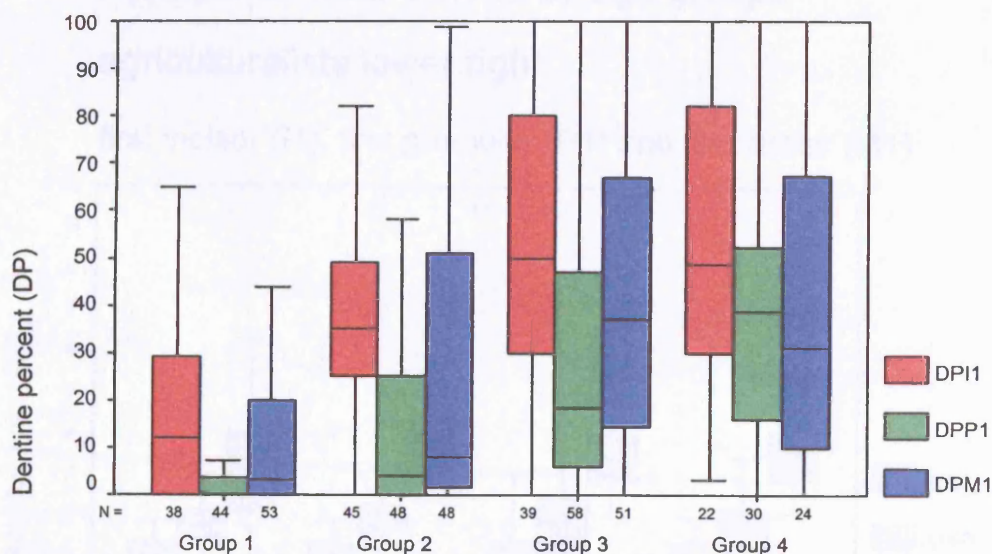


Figure 7.30: Box plot of the dentine percent of first incisor (I1), first premolar (P1) and first molar (M1) of the agriculturalists divided by the age groups. (Group 1= young 20-25 years, Group 2=middle adult 1 25-35 years, Group 3= middle adult 2 35-45 years and Group 4= old adult 45+ years).

For the agriculturalists (Figure 7.30) the pattern of differences between teeth is similar to that of the full collection, non-agriculturalists and transitionals (Figure 7.18, 7.22 and 7.26), but the trend with age is less marked. In particular whilst the medians increase from age group 1 to age group 2, and to age group 3, there is no further increase into age group 4. Changes are however statistically significant (Table 7.16).



Kruskal-Wallis test Dentine percent

	AGE	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Dentine percent I1	20-25 young	38	41.45	34.473	3	0.000
	25-35 middle adult 1	45	72.44			
	35-45 middle adult 2	39	90.72			
	45+ old adult	22	93.95			
	Total	144				
Dentine percent for P1	20-25 young	44	53.40	44.391	3	0.000
	25-35 middle adult 1	48	80.92			
	35-45 middle adult 2	58	111.53			
	45+ old adult	30	119.58			
	Total	180				
Dentine percent for M1	20-25 young	53	63.72	8.483	3	0.037
	25-35 middle adult 1	48	67.36			
	35-45 middle adult 2	51	81.22			
	45+ old adult	24	88.52			
	Total	176				

Table 7.16: Kruskal-Wallis test of the dentine percent for first incisor (I1), first premolar (P1) and first molar (M1) divided by the age groups.

### Approximal wear

Approximal wear divided by age groups

agriculturalists lower right

first incisor (I1), first premolar (P1) and first molar (M1)

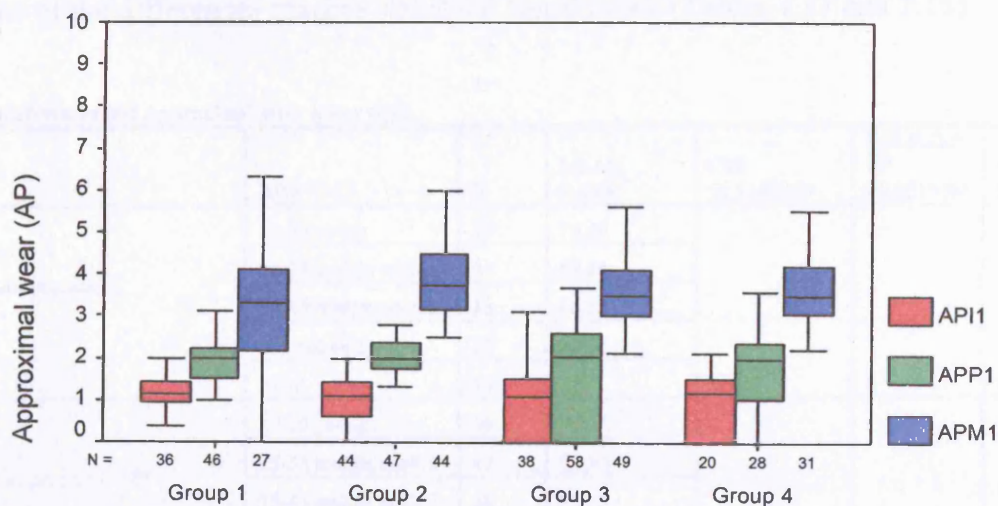


Figure 7.31: Box plot of the approximal wear (AP) lower right of first incisor (I1), first premolar (P1) and first molar (M1) of the agriculturalists divided by the age groups. (Group 1= young 20-25 years, Group 2=middle adult 1 25-35 years, Group 3= middle adult 2 35-45 years and Group 4= old adult 45+ years).

## Approximal wear divided by age groups

### agriculturalists lower left

first incisor (I1) first premolar (P1) first molar (M1)

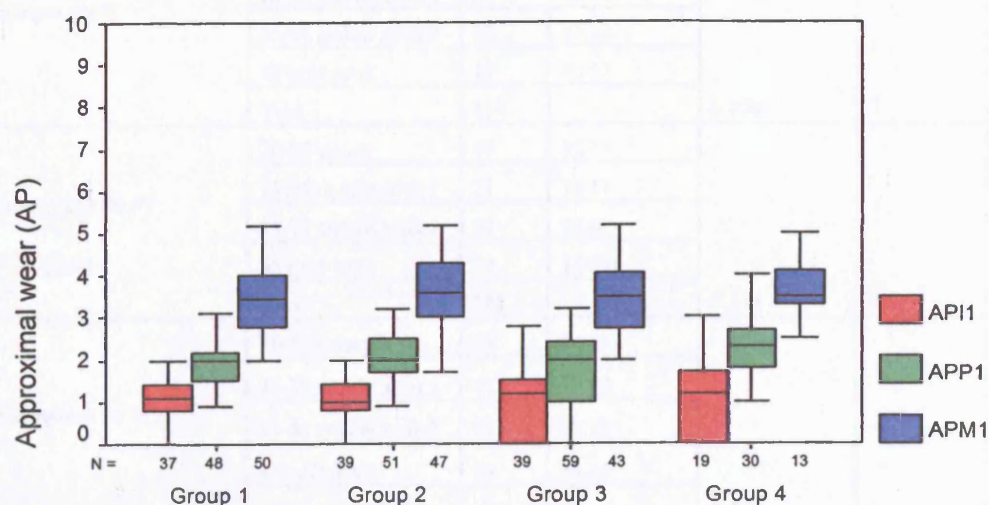


Figure 7.32: Box plot of the approximal wear (AP) lower left of first incisor (I1), first premolar (P1) and first molar (M1) of the agriculturalists divided by the age groups. (Group 1= young 20-25 years, Group 2=middle adult 1 25-35 years, Group 3= middle adult 2 35-45 years and Group 4= old adult 45+ years).

Whilst the differences between teeth are similar to the full collection, non-agriculturalist, and transitionals (Figures 7.19, 7.20, 7.23, 7.24, 7.27 and 7.28), Figure 7.32 shows that the agriculturalists do not show a strong trend of approximal wear facet length with age. None of the differences reaches statistical significance (Tables 7.17 and 7.18).

Kruskal-Wallis test Approximal wear lower right

	AGE	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Dentine percent I1	20-25 young	36	73.49	0.590	3	0.890
	25-35 middle adult 1	44	69.14			
	35-45 middle adult 2	38	66.55			
	45+ old adult	20	68.72			
	Total	138				
Dentine percent for P1	20-25 young	46	84.93	0.998	3	0.802
	25-35 middle adult 1	47	93.30			
	35-45 middle adult 2	58	93.13			
	45+ old adult	28	86.30			
	Total	179				
Dentine percent for M1	20-25 young	51	73.93	5.777	3	0.123
	25-35 middle adult 1	46	94.96			
	35-45 middle adult 2	49	91.87			
	45+ old adult	24	78.96			
	Total	170				

Table 7.17: Kruskal-Wallis test of the lower right approximal wear for first incisor (I1), first premolar (P1) and first molar (M1) divided by the age groups.



Kruskal-Wallis test Approximal wear lower left

	AGE	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Dentine percent I1	20-25 young	37	68.64	0.820	3	0.845
	25-35 middle adult 1	39	63.94			
	35-45 middle adult 2	39	67.13			
	45+ old adult	19	73.37			
	Total	134				
Dentine percent for P1	20-25 young	48	85.15	6.514	3	0.089
	25-35 middle adult 1	51	98.17			
	35-45 middle adult 2	59	88.68			
	45+ old adult	30	114.68			
	Total	188				
Dentine percent for M1	20-25 young	50	74.68	1.575	3	0.665
	25-35 middle adult 1	47	82.70			
	35-45 middle adult 2	43	72.12			
	45+ old adult	13	81.46			
	Total	153				

Table 7.18: Kruskal-Wallis test of the lower right approximal wear for first incisor (I1), first premolar (P1) and first molar (M1) divided by the age groups.

### Occlusal wear plane angles

Occlusal wear plane angle divided by age

groups agriculturalists

first molar (M1) second molar (M2)

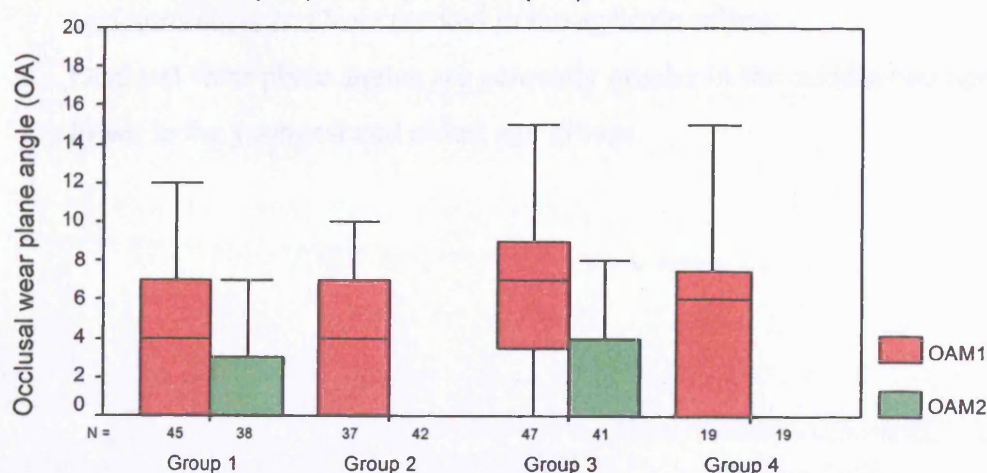


Figure 7.33: Box plot of the occlusal wear plane angle (OA) of first molar (M1) and second molar (M2) of the agriculturalists divided by the age groups. (Group 1= young 20-25 years, Group 2= middle adult 1 25-35 years, Group 3= middle adult 2 35-45 years and Group 4= old adult 45+ years).

Figure 7.33 shows that, for the agriculturalists, the first two age groups have lower median occlusal wear plane angles than the older two age groups. These differences, however, are not statistically significant (Table 7.19).

**Kruskal-Wallis test Occlusal wear plane angle**

	AGE	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Dentine percent M1	20-25 young	45	68.96	5.567	3	0.135
	25-35 middle adult 1	37	67.36			
	35-45 middle adult 2	47	86.27			
	45+ old adult	19	72.42			
	Total	148				
Dentine percent for M2	20-25 young	38	68.37	3.059	3	0.383
	25-35 middle adult 1	42	67.98			
	35-45 middle adult 2	41	77.66			
	45+ old adult	19	64.89			
	Total	140				

Table 7.19:Kruskal-Wallis test of the occlusal wear plane angle for first molar (M1) and second molar (M2) divided by the age groups.

**Summary**

1. Within each age group, the proportion of dentine exposure on the occlusal surface is greater in M1 than I1 and P1.
2. Occlusal attrition increases with age and this trend is most marked in the non-agriculturalists and least marked in the agriculturalists with the transitionals in between.
3. Approximal wear facet lengths are largest in M1 and smallest in I1.
4. Approximal facet lengths increase with age in the first three age groups but decreases in the last age group, this trend is most marked in the non-agriculturalists and least marked in the agriculturalists.
5. Occlusal wear plane angles are generally greater in the middle two age groups and lower in the youngest and oldest age groups.

### 7.1.C Strong gradient of wear from front to back

This section tests the hypothesis that there is a gradient of wear from the front of the jaw to the back. Box plots of the dentine percent and approximal wear are presented, first showing the full collection and then separated by behavioural groups.

#### Dentine percent

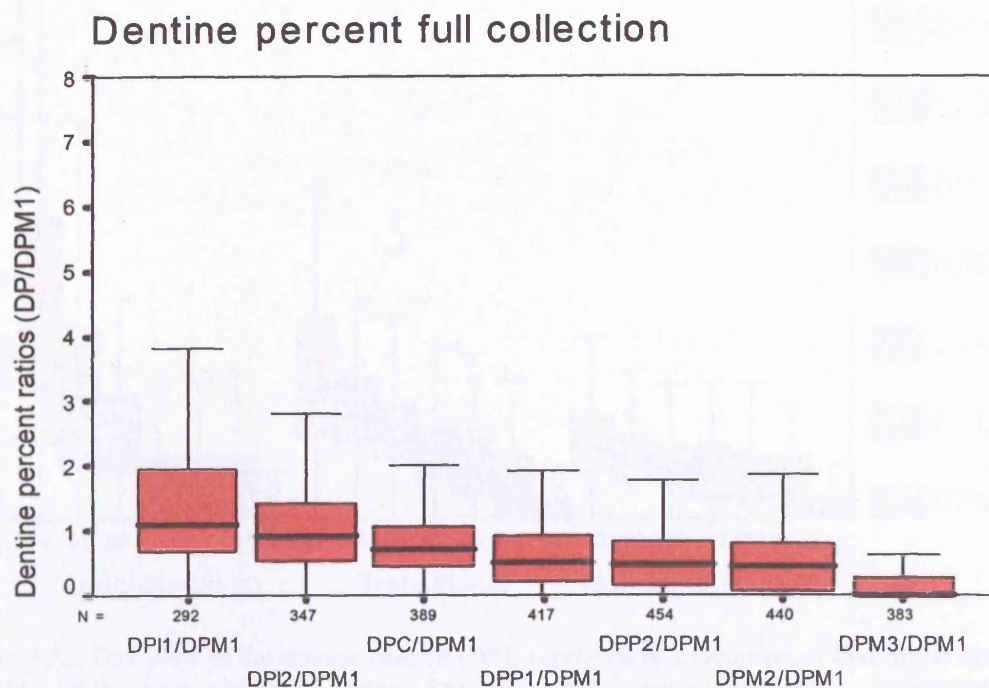


Figure 7.34: Box plots of the dentine percent (DP), expressed as proportion of first molar dentine percent (DPM1), for the full collection. Proportions are shown for first incisor (I1), second incisor (I2), canine (C), first and second premolars (P1 and P2), second and third molars (M2 and M3).

Figure 7.34 shows that the median dentine percent ratio decreases along the dental arcade from I1 to M3. The medians for I1 and I2 are almost 1, showing a similar amount of occlusal wear on average to M1, as might be expected because they erupt at a similar age. The ratio for I1 is just a little above 1 and the ratio for I2 is a little below which may reflect the slight difference in their eruption timing. The rest of the dentition has a ratio below 1 showing that they have on average less occlusal wear than M1. This would most likely be expected because of eruption timing (chapter 2, Dental Anatomy). In effect the dentine percent ratio follows the order of eruption. Therefore there does appear to be a gradient of wear along the dental arcade but there is good evidence to suggest it follows the timing of eruption. The incisors, particularly I1 have a larger interquartile range for their dentine percent ratios than the other teeth.



## Dentine percent divided by behavioural groups

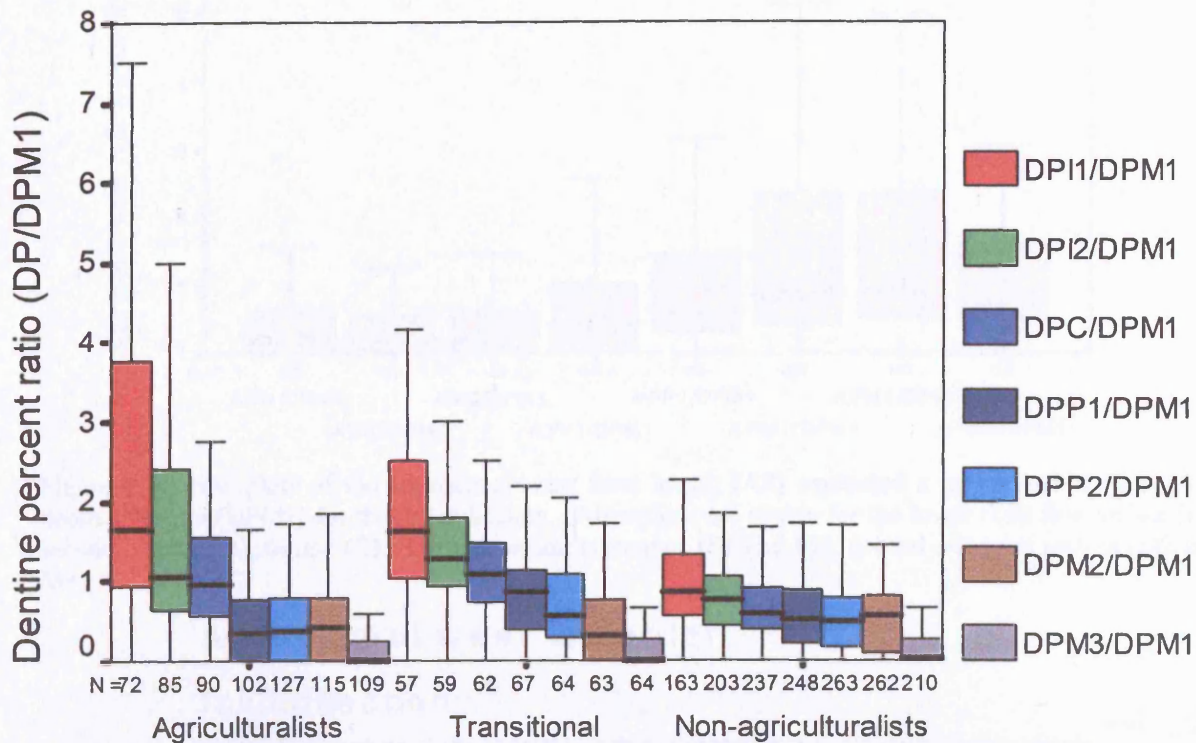


Figure 7.35: Box plots of the dentine percent (DP), expressed as proportion of first molar dentine percent (DPM1), for the three behavioural groups. Proportions are shown for first incisor (I1), second incisor (I2), canine (C), first and second premolars (P1 and P2), second and third molars (M2 and M3).

Figure 7.35 shows a similar pattern to the full collection above for all three behavioural groups. The non-agriculturalists show a pattern most like the full collection with I1 and I2 ratios around 1, and the rest of the dentition is lower than 1. In the transitionals and agriculturalists C ratio is around 1 and the I1, I2 ratios are considerably above. In the agriculturalists there is a marked difference between the anterior teeth and cheek teeth, where as the transitionals show a more gradual decrease. As in the dentine percent box plot above (Figure 7.34), I1 has the largest interquartile ranges. This is least marked in the non-agriculturalists and most marked in the agriculturalists.

### Approximal wear

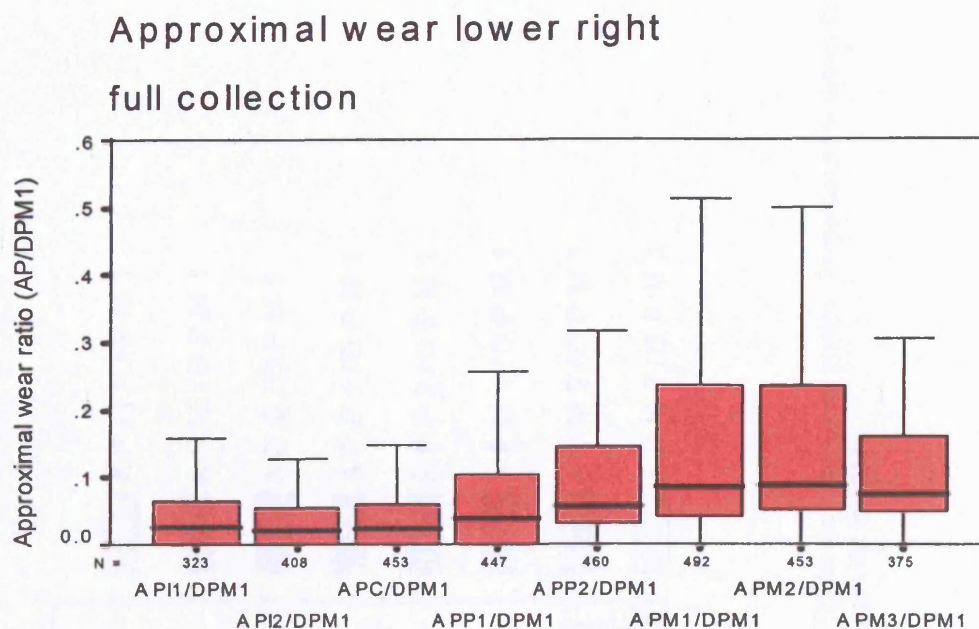


Figure 7.36: Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the full collection. Proportions are shown for the lower right first incisor (I1), second incisor (I2), canine (C), first and second premolars (P1 and P2), second and third molars (M2 and M3).

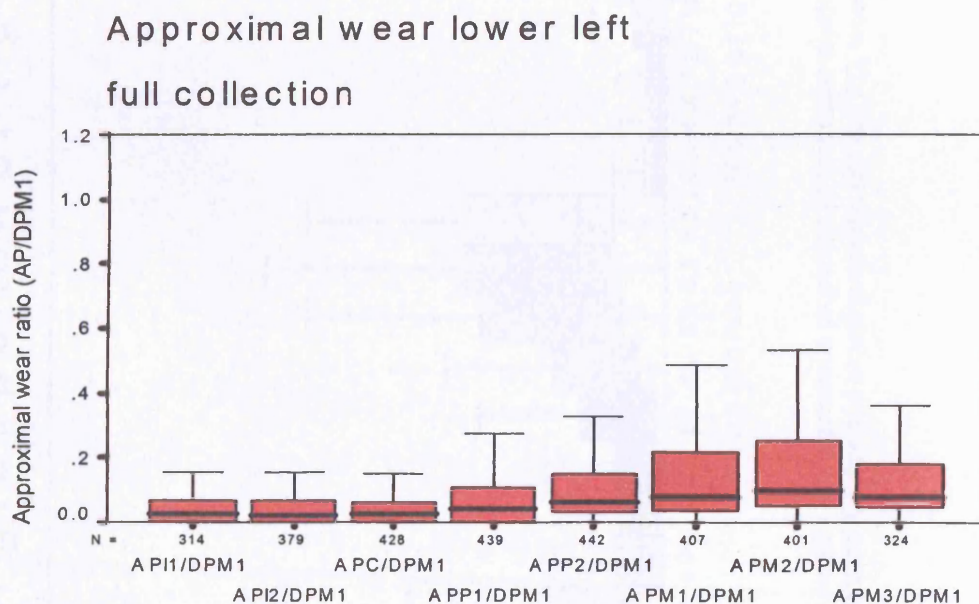


Figure 7.37: Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the full collection. Proportions are shown for the lower left first incisor (I1), second incisor (I2), canine (C), first and second premolars (P1 and P2), second and third molars (M2 and M3).

In Figures 7.36 and 7.37, the approximal wear ratio is lowest in the anterior teeth and highest in M1 and M2. The premolars have intermediate values and M3 has lower values than the other molars. This pattern might be expected from the relative sizes of the crowns of the different teeth. Interquartile ranges are smallest in the anterior teeth and largest in M1 and M2. All interquartile ranges in the left dentition are smaller than those in the right dentition.



## Approximal wear divided by behavioural groups lower right

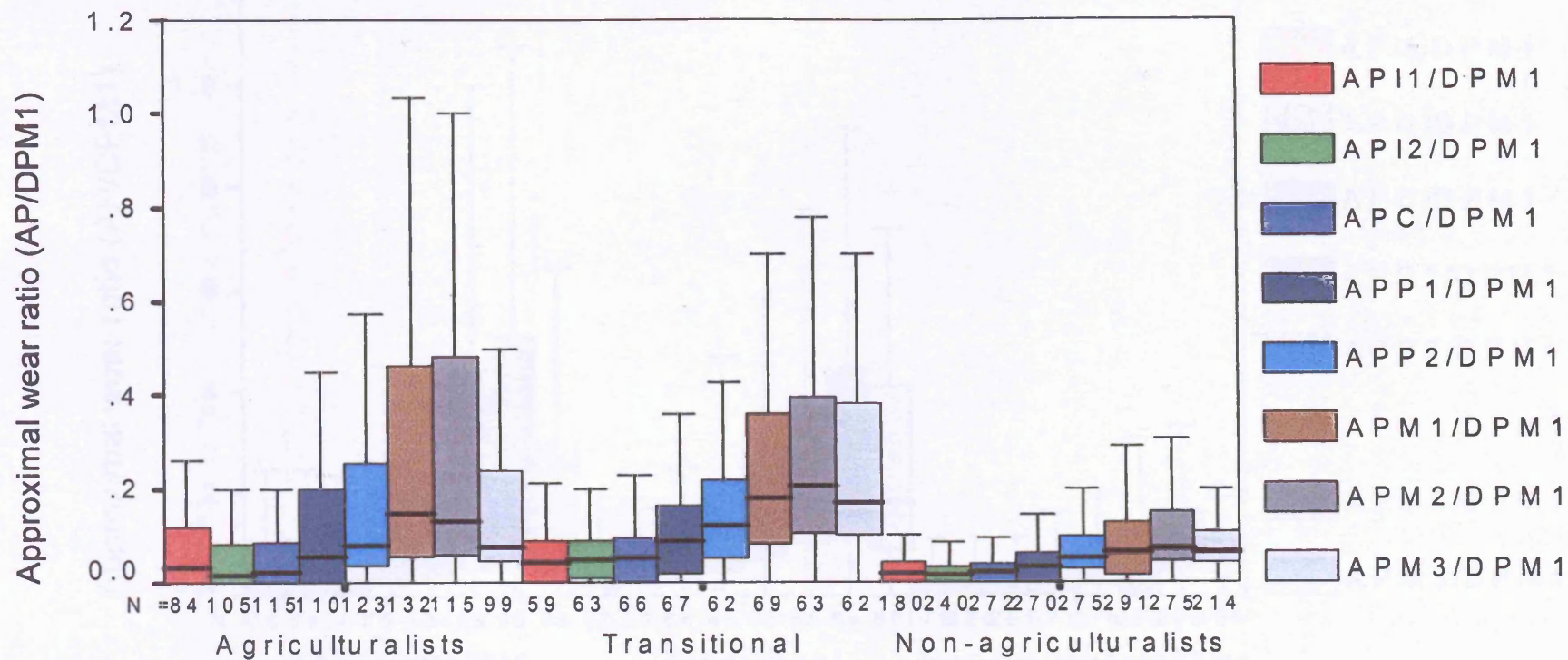


Figure 7.38: Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the behavioural groups. Proportions are shown for the lower right first incisor (I1), second incisor (I2), canine (C), first and second premolars (P1 and P2), second and third molars (M2 and M3).

## Approximal wear divided by behavioural groups lower left

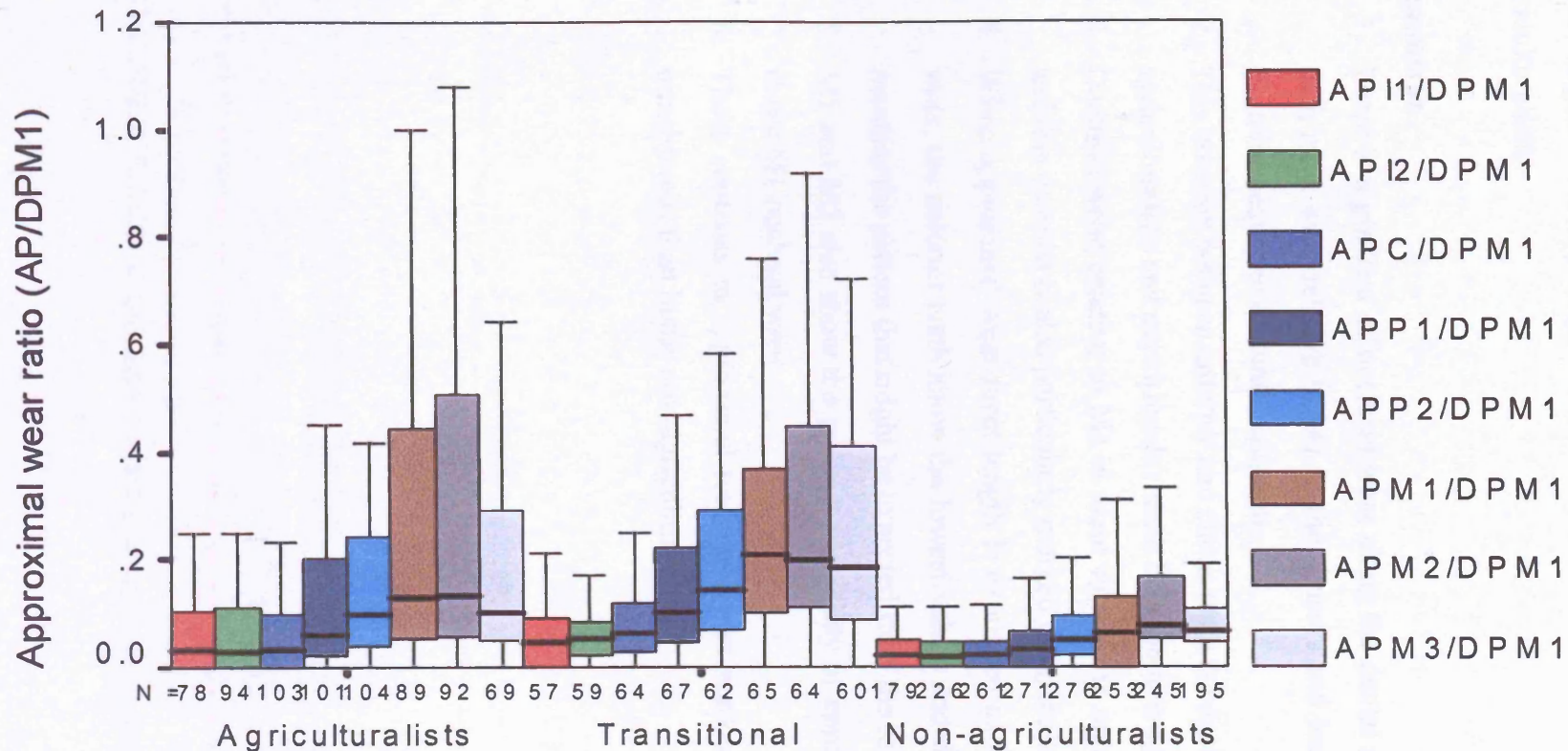


Figure 7.39: Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the behavioural groups. Proportions are shown for the lower left first incisor (I1), second incisor (I2), canine (C), first and second premolars (P1 and P2), second and third molars (M2 and M3).

When the behavioural groups are plotted separately it is apparent that the differences between molars and anterior teeth are much more marked in the agriculturalists and transitionals than they are in the non-agriculturalists. Not only are the median ratios for M1 and M2 much higher than the ratios for I1-C, but the interquartile ranges are also much larger. If anything, this pattern is more marked in the transitionals than the agriculturalists.

**Summary:**

1. There is a gradient of occlusal wear along the dental arcade from mesial to distal with most wear relative to M1 in the incisors and least in M3. This is expected from the sequence of dental eruption.
2. This contrast between anterior and cheek teeth is considerably more marked in the agriculturalists and transitionals than it is in the non-agriculturalists.
3. Occlusal wear, relative to M1 is more variable in anterior teeth than cheek teeth, and this contrast is also particularly marked in agriculturalists and transitionals.
4. When approximal wear facet length is expressed as a proportion of M1 occlusal wear, the anterior teeth show the lowest values and the molars the highest. This matches the pattern that might be expected from the relative sizes of the crowns.
5. M1 and M2 also show the greatest variability of approximal facet length relative to the M1 occlusal wear.
6. These contrasts in approximal wear are more marked in the agriculturalists and transitionals than in the non-agriculturalists.

The order of the plots and tests is standard throughout this results section:

- scatter plots
- box plots
- Kruskal-Wallis tests

The scatter plots show wear scores for each tooth type plotted against scores for the M1 occlusal wear. The different groups are represented as contrasting coloured points. The box plots show the wear scores for each tooth type, expressed as ratios of M1 occlusal wear. The different boxes of the plots represent the various groups. Kruskal-Wallis tests compare the variation in these wear score ratios between the different groups. Differences are regarded as statistically significant at  $p \leq 0.05$ . The ratios are presented in three groups: the anterior teeth (I1, I2 and C), the cheek teeth (first P1 and P2) and the posterior teeth (M1, M2 and M3).

## **7.2: Comparison of the full collection**

In this section, males, females and all age groups are included together. Comparisons are made between:

- all assemblages together
- coastal assemblages
- inland collections
- North American assemblages compared with the Levant assemblages

### **7.2.A. Combined coastal, inland, North American and Levant assemblages**

The non-agricultural assemblages; Carlston Annis, Chiggerville, El Wad, Kebara, Indian Knoll and Santa Barbara Channel Islands are plotted against the transitional collection; Calhoun County and against the agricultural assemblages; Abu Hureyra, Florida Canaveral Peninsula, Hawikuh and Shannon.

## **Dentine percent**



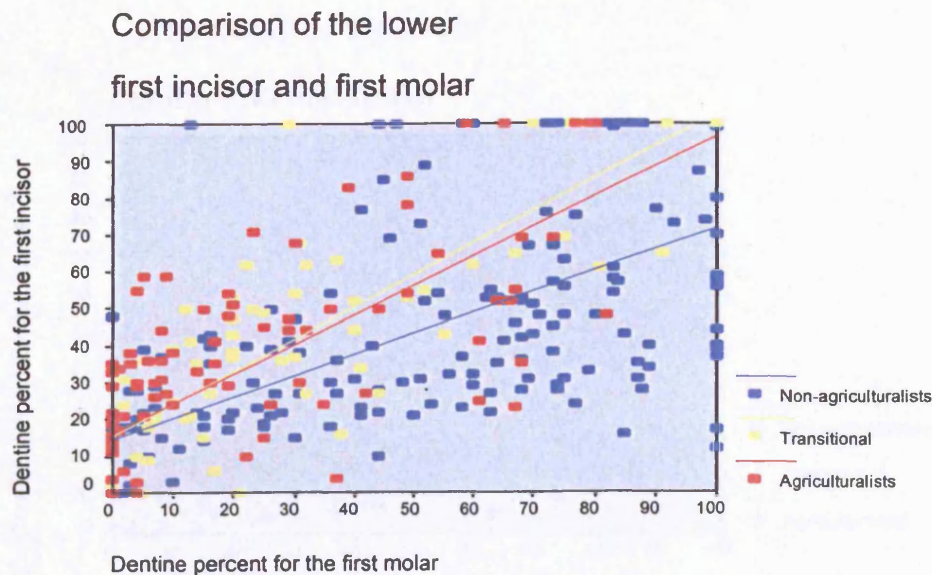


Figure 7.40: Scatter plot of the dentine percent of I1 plotted against M1 from the behavioural groups.

Figure 7.40 shows I1 dentine percent plotted against M1 dentine percent. There is a general trend of increasing I1 wear for increasing molar wear, but the graph shows a good deal of variation. The scatters of points for all three assemblages overlap, but the transitional and agricultural groups overlap to a greater extent than either overlaps with the non-agriculturalists. In addition, the trend of points in the transitional and agriculturalists scatters rises more steeply than the non-agriculturalists scatter. This implies that I1 wear is generally more advanced for any given stage of M1 wear in the transitionals and agriculturalists than it is in the non-agriculturalists.

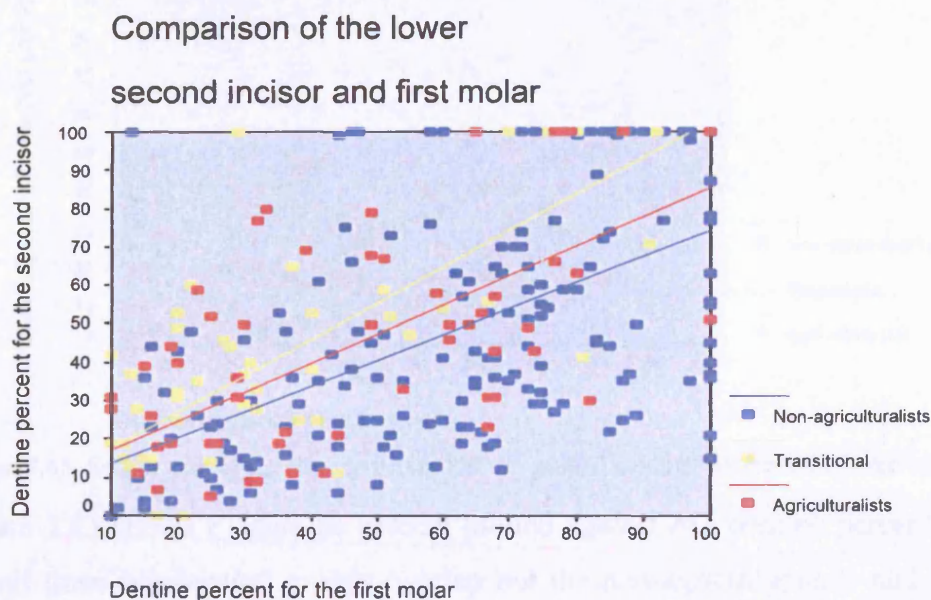


Figure 7.41: Scatter plot of the dentine percent of I2 plotted against M1 from the behaviour groups.



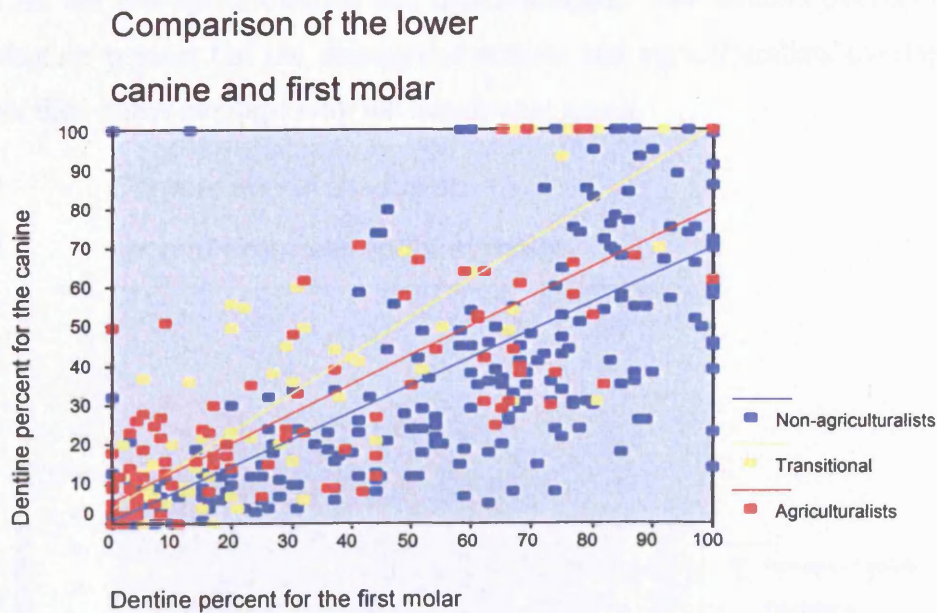


Figure 7.42: Scatter plot of the dentine percent on C plotted against M1 from the behavioural groups.

The equivalent plots for I2 and C (Figures 7.41 and 7.42) show a greater degree of variability, with more overlap between the point scatters for the different assemblages. Once again however, the transitionals and agriculturalists scatters show a slightly steeper slope than the non-agriculturalists scatter.

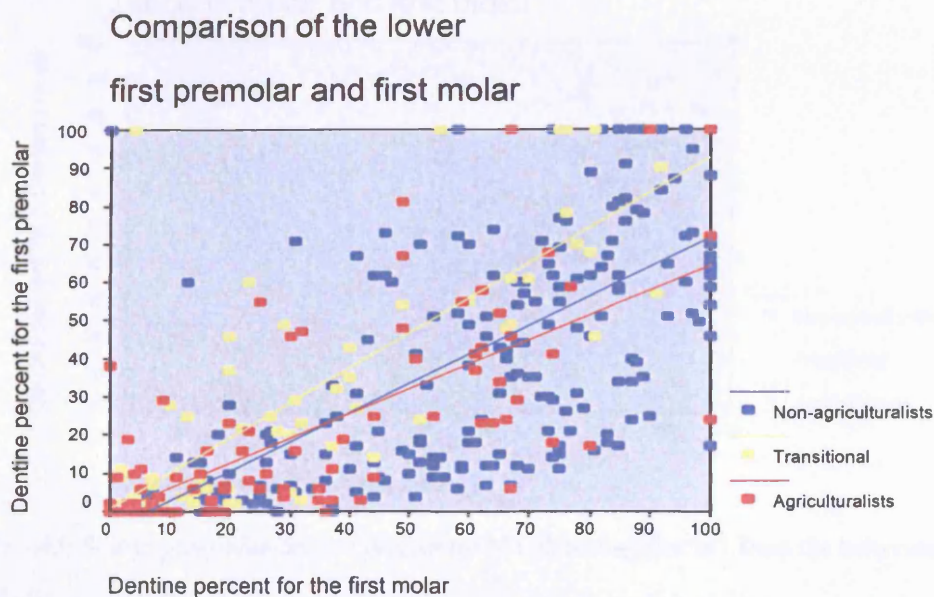


Figure 7.43: Scatter plot of the dentine percent for P1 plotted against M1 from the behaviour groups.

Figure 7.43 shows P1 dentine percent plotted against M1 dentine percent. The scatters for all three behavioural groups overlap but the non-agriculturalists and agriculturalists overlap to a greater extent than either overlaps with the transitional group. The transitional group however, has a steeper slope of scatters than that the non-agriculturalists and agriculturalists. Similarly P2 dentine percent plotted against M1 dentine percent (Figures 7.44 below) shows a steeper slope for the transitionals scatters

than for the non-agriculturalists and agriculturalists. The scatters overlap more than for P1 dentine percent but the non-agriculturalists and agriculturalists overlap to a greater extent than either overlaps with the transitional group.

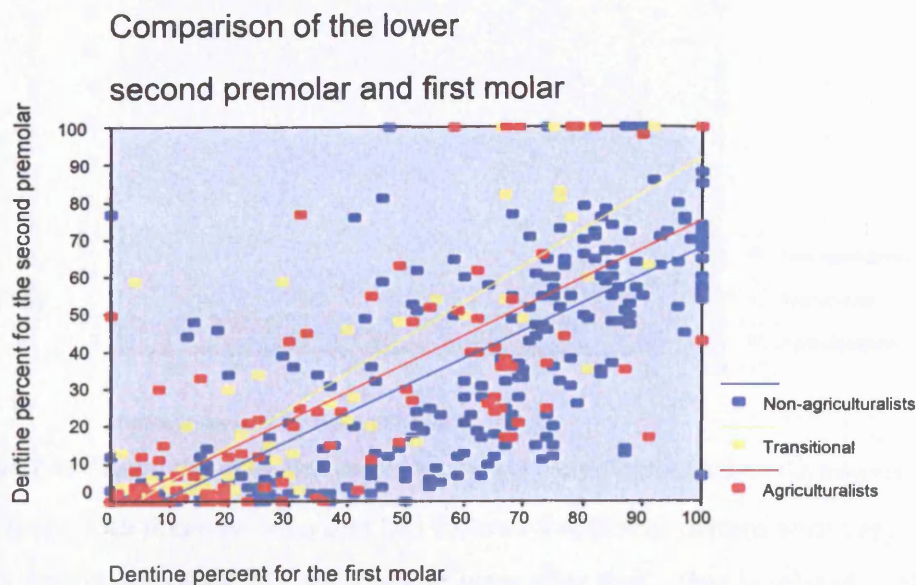


Figure 7.44: Scatter plot of the dentine percent for P2 plotted against M1 from the behaviour groups.

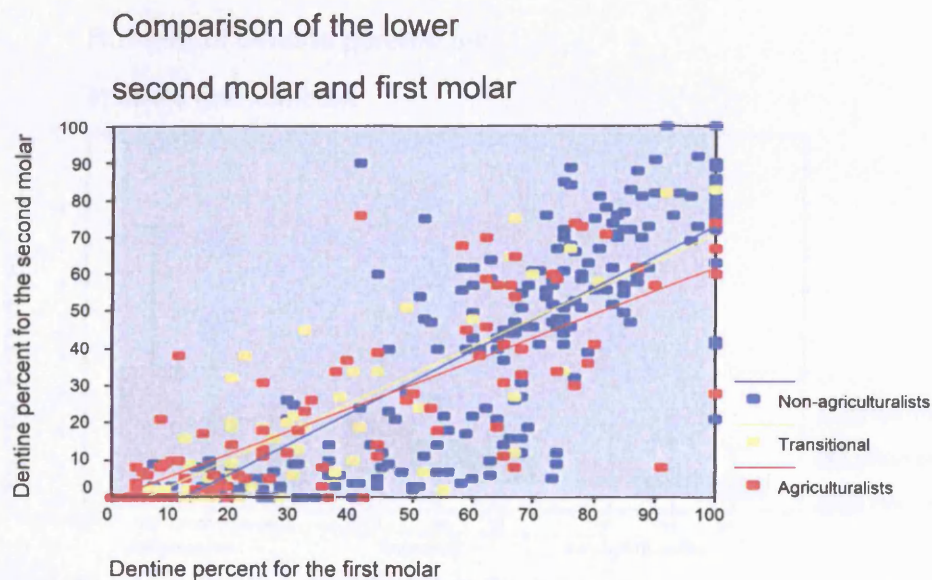


Figure 7.45: Scatter plot of the dentine percent for M2 plotted against M1 from the behaviour groups.

For M2 (Figure 7.45) the scatters for all three behavioural groups overlap greatly. There is much less slope of gradient than the anterior teeth. This implies that there is less difference between the dentine exposure for the posterior teeth than in the anterior teeth.



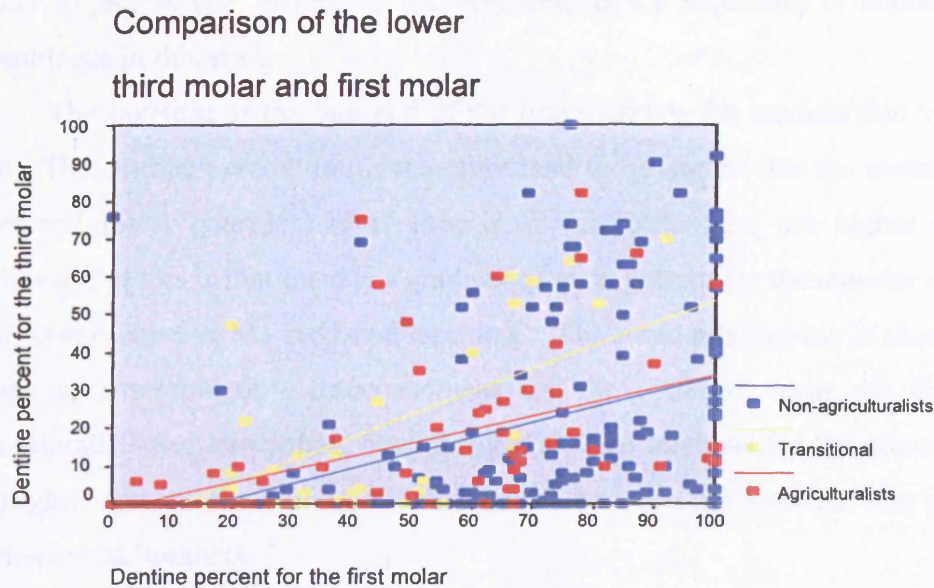


Figure 7.46: Scatter plot of the dentine percent for M3 plotted against M1 on the behaviour groups.

In Figure 7.46 it can be seen that M3 follows a different pattern with very little wear up to 50% dentine exposure M1 and marked wear after that. This is related to the late eruption of the M3.

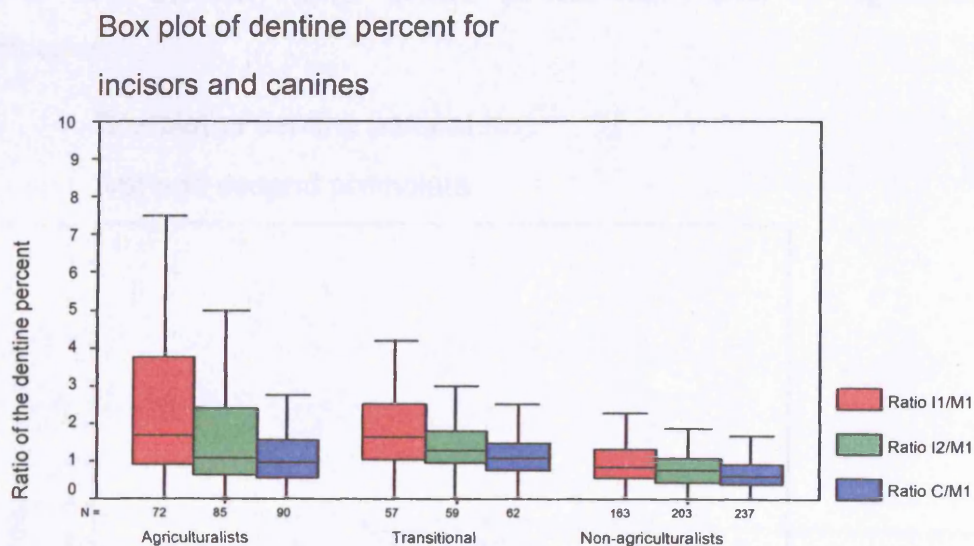


Figure 7.47: Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for the full collection. Proportions are shown for the first incisor (I1), second incisor (I2), and canine (C).

Figure 7.47 shows the incisors and C ratios separately for the agriculturalists, transitionals and non-agriculturalists. In general the interquartile range (expressed by the height of the box) of the I1/M1 is greater than that of I2/M1 which in turn, is greater than the interquartile range of the C/M1. A similar progression is shown to some extent by the overall range, expressed by the length of the "whiskers". For all three tooth types, the interquartile range is greater in the agriculturalists, least in the non-agriculturalists and intermediate in the transitionals. This implies that the agriculturalists show the greatest

variety in pattern (i.e. difference between teeth in the dentition) of dental wear for the assemblages in this study.

The position of the box and of the line marking the median also varies between teeth. The dentine percent ratios therefore tend to be higher (for the median and for the upper and lower quartiles) in I1 than in I2 which in turn, are higher than C. The implication of this is that there is a gradient of wear pattern for the anterior dentition, with most wear relative to M1 in I1 and least in C. The same relationship is shown in all three groups of assemblages. Ratio medians for the different teeth are similar for the agriculturalists and transitional assemblages, and the medians for the non-agriculturalists are slightly lower. In addition, the differences between the teeth are less pronounced in the non-agriculturalists.

To summarise, there is a gradient of variability and degree in the dentine percent ratios along the anterior tooth row, with highest values and greatest variability in I1 and lowest values, least variability in C. This trend is shown most strongly in the agriculturalists and least strongly in the non-agriculturalists. The non-agriculturalists also tend to have generally lower dentine percent ratios than the agriculturalists and transitionals.

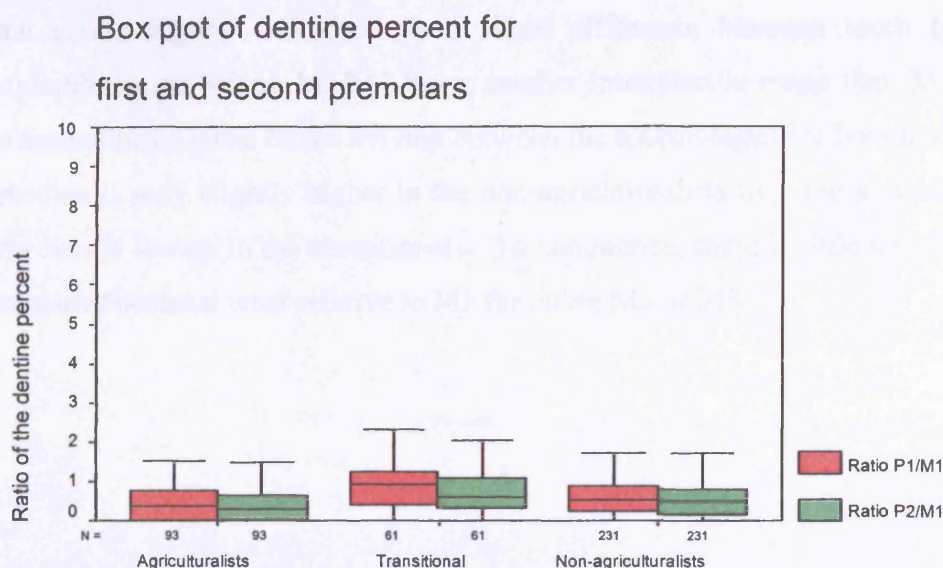


Figure 7.48: Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for the full collection. Proportions are shown first and second premolars (P1 and P2).

For the plot of the premolars (Figure 7.48) there is much less difference (compared with Figure 7.47) between the tooth types in interquartile range. In addition, there is more overlap in the positions of the boxes and more similarity in the medians. Overall, P1 shows slightly higher median ratios than P2, but the difference is small. In the same way there are only modest differences between the three groups of assemblages, and the interquartile ranges represented by the boxes overlap extensively. Both the median and



interquartile ranges of the transitional group are slightly higher than those of the other two groups, but the difference is not large. To summarise, there are only small variations between premolars and between groups of assemblages in occlusal wear relative to M1, although there are slightly higher wear ratios for transitionals than for non-agriculturalists or agriculturalists.

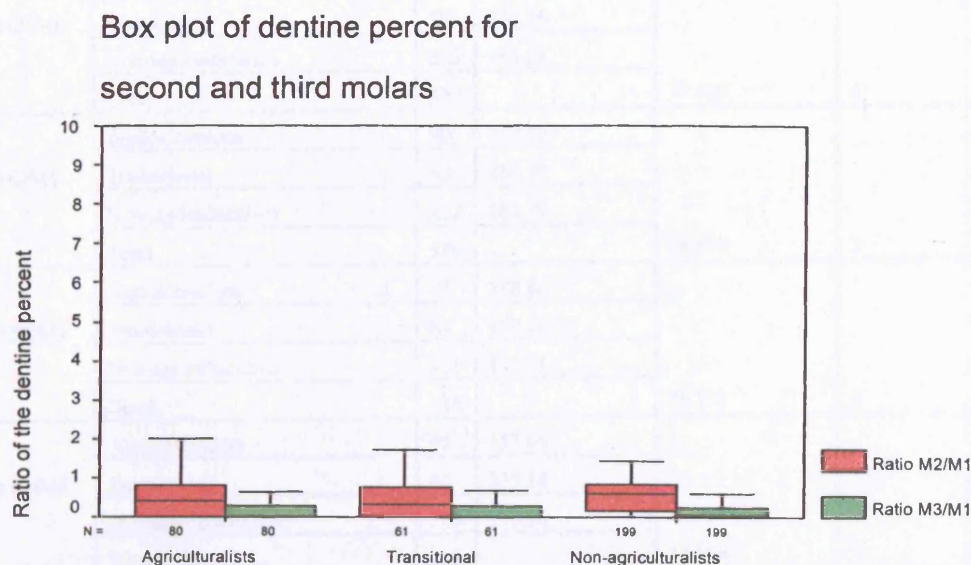


Figure 7.49: Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for the full collection. Proportions are shown for second and third molars (M2 and M3).

In the above Figure 7.49 there is a slight difference between tooth types in the interquartile range, where M3/M1 has a smaller interquartile range than M2/M1 for all three assemblages. The boxes overlap between the assemblages for both tooth types, but the median is only slightly higher in the non-agriculturalists than the agriculturalists and the median is lowest in the transitionals. To summarise, there is little variation between assemblages occlusal wear relative to M1 for either M2 or M3.



Kruskal-Wallis mean ranks

	BEHAVIOURAL GROUPS	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Ratio I1/M1	Agriculturalists	72	183.74	41.215	2	.000
	Transitional	57	180.10			
	Non-agriculturalists	163	118.30			
	Total	292				
Ratio I2/M1	Agriculturalists	85	204.45	37.839	2	.000
	Transitional	59	224.36			
	Non-agriculturalists	203	146.61			
	Total	347				
Ratio C/M1	Agriculturalists	90	237.31	50.874	2	.000
	Transitional	62	256.70			
	Non-agriculturalists	237	162.79			
	Total	389				
Ratio P1/M1	Agriculturalists	93	158.86	26.153	2	.000
	Transitional	61	252.20			
	Non-agriculturalists	231	191.11			
	Total	385				
Ratio P2/M1	Agriculturalists	93	157.05	17.994	2	.000
	Transitional	61	233.18			
	Non-agriculturalists	231	196.86			
	Total	385				
Ratio M2/M1	Agriculturalists	80	155.01	5.649	2	.059
	Transitional	61	156.19			
	Non-agriculturalists	199	181.12			
	Total	340				
Ratio M3/M1	Agriculturalists	80	169.21	.893	2	.649
	Transitional	61	161.49			
	Non-agriculturalists	199	173.78			
	Total	340				

Table 7.20: Kruskal-Wallis test of the dentine percent, expressed as proportion of the first molar dentine percent, for the different behavioural groups. Proportions are shown for the first and second incisors (I1 and I2), canine (C), first and second premolars (P1 and P2), second and third molars (M2 and M3).

The Kruskal-Wallis test (Table 7.20) results for the anterior teeth show that the differences between medians seen in Figure 7.47 are statistically highly significant. There is therefore good evidence that, in the material studied here, agriculturalists and transitionals have higher dentine percent ratios than non-agriculturalists for all three anterior teeth. In spite of the small differences medians seen in Figure 7.48, the Kruskal-Wallis test shows that these differences are highly significant for both premolars. The largest ratios are found in the transitional group, and the lowest in the agriculturalists. The molars show no significant differences in their median ratios. This reflects the large degree of overlap shown in both box plot (Figure 7.49) and scatter plots (Figures 7.45 and 7.46).

### Approximal facet length

As seen in the correlations coefficient tests (7.1 Preliminary Results) the lower right and left sides are not strongly symmetrical, therefore the results are presented separately for the left and right sides.

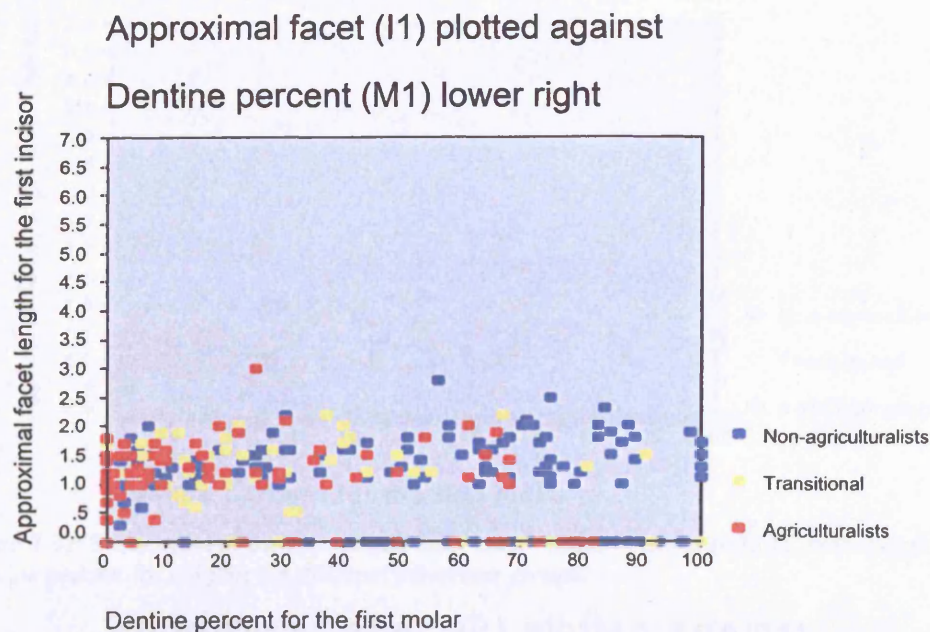


Figure 7.50: Scatter plot of the approximal facet length (mm) of lower right I1 plotted against occlusal wear (dentine percent for M1) for the different behaviour groups.

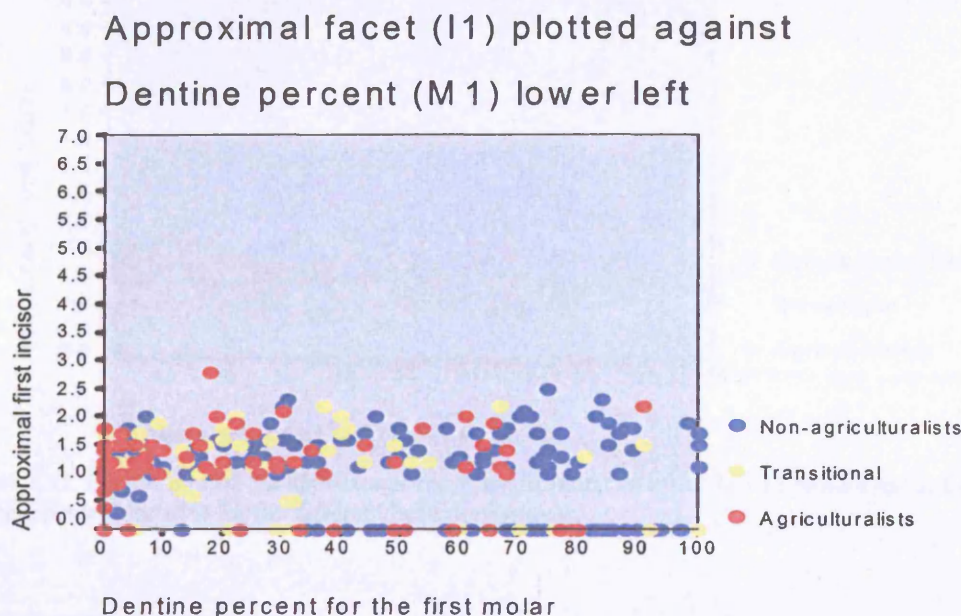


Figure 7.51: Scatter plot of the approximal facet length (mm) of lower left I1 plotted against occlusal wear (dentine percent for M1) for the different behaviour groups.

Similarly to the Figures 7.40-7.46 (full collection), the plots for I1, I2, C, (Figures 7.50 - 7.55) shows the scatters of points for the different behavioural groups overlap extensively, but there are some slight variations between them. The scatters for the

agriculturalists and transitionals are positioned slightly differently, with generally lower scatter values for M1 dentine percent but there are no marked differences in the plot.

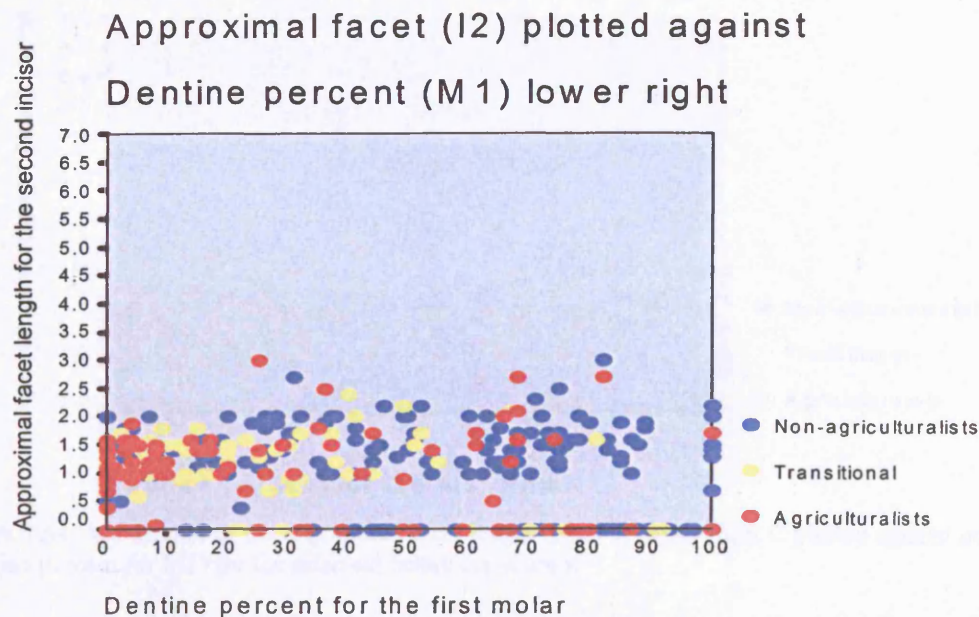


Figure 7.52: Scatter plot of the approximal facet length (mm) of lower right I2 plotted against occlusal wear (dentine percent for M1) for the different behaviour groups.

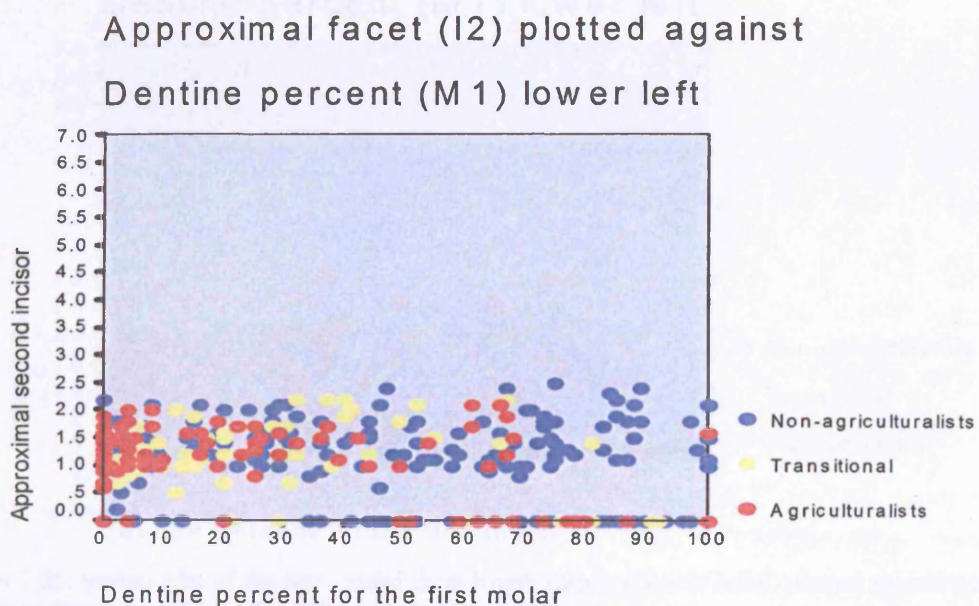


Figure 7.53: Scatter plot of the approximal facet length (mm) of lower left I2 plotted against occlusal wear (dentine percent for M1) for the different behaviour groups.



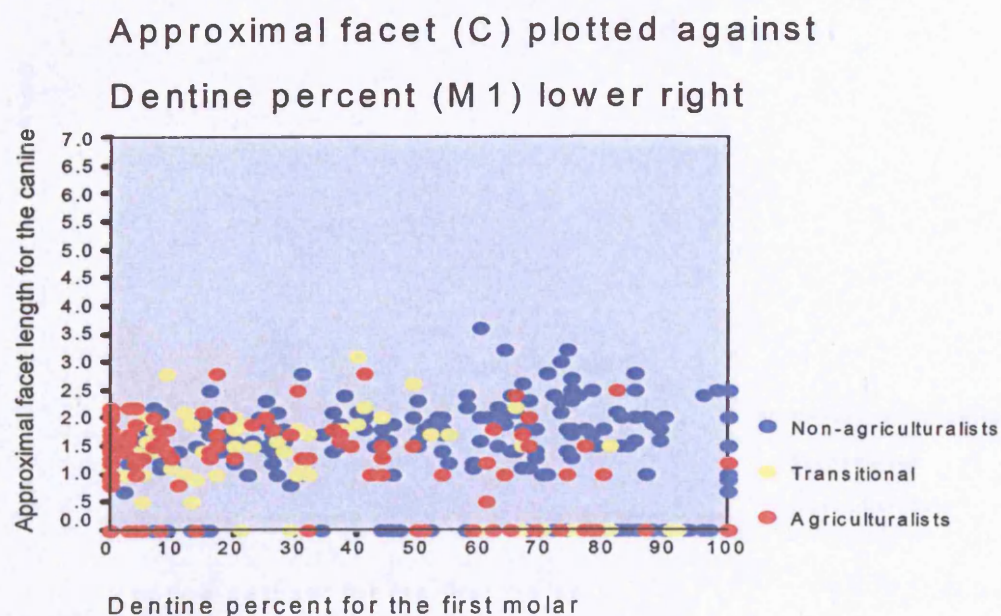


Figure 7.54: Scatter plot of the approximal facet length (mm) of lower right C plotted against occlusal wear (dentine percent for M1) for the different behaviour groups.

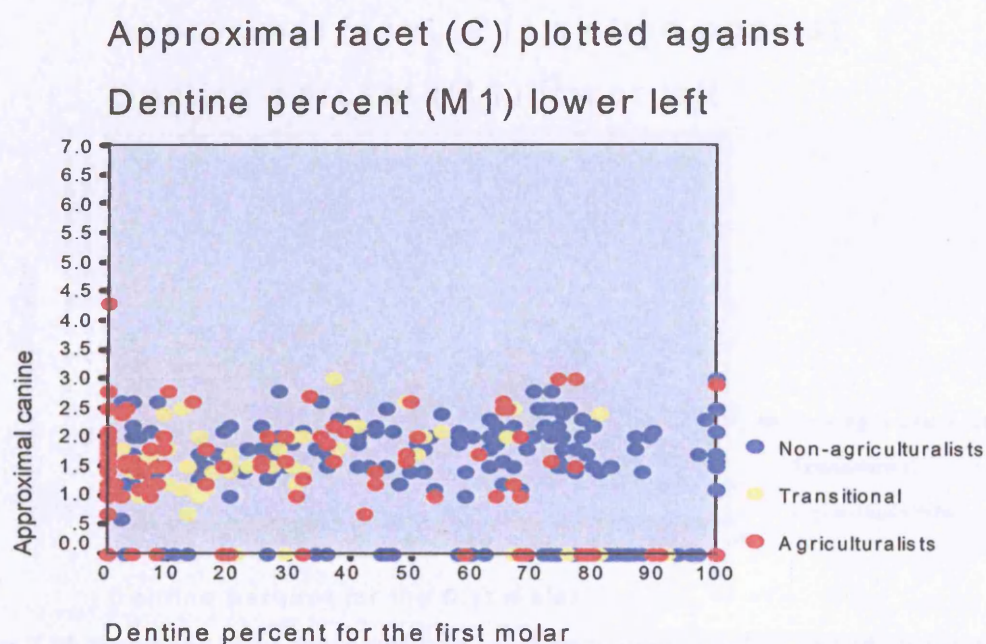


Figure 7.55: Scatter plot of the approximal facet length (mm) of lower left C plotted against occlusal wear (dentine percent for M1) for the different behaviour groups.

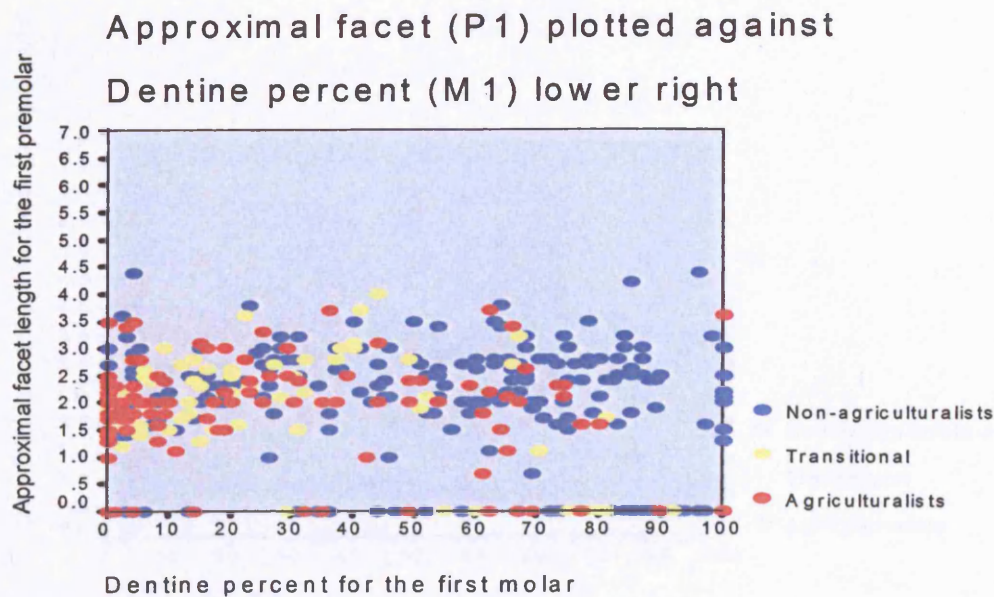


Figure 7.56: Scatter plot of the approximal facet length (mm) of lower right P1 plotted against occlusal wear (dentine percent for M1) for the different behaviour groups.

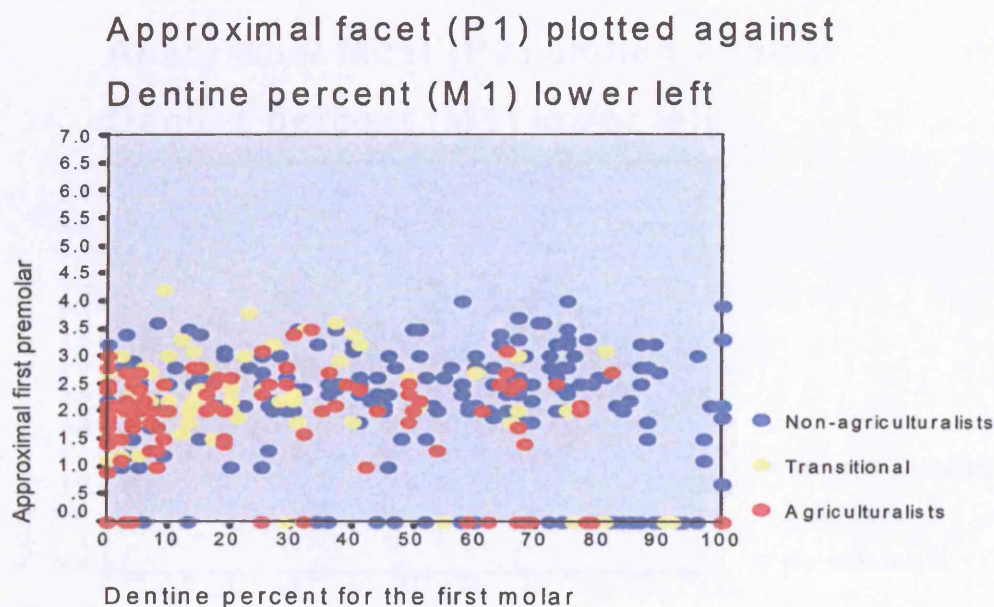


Figure 7.57: Scatter plot of the approximal facet length (mm) of lower left P1 plotted against occlusal wear (dentine percent for M1) for the different behaviour groups.

The scatter plots for P1 and P2 (Figures 7.56 - 7.59) show generally larger approximal wear facets than in the anterior teeth above. They also show greater variability with larger spread of values. This is particularly marked in P2. The non-agriculturalists show consistently longer approximal wear facets in the higher grades of M1 occlusal wear than the transitionals and agriculturalists. This trend is to some extent in C also but much more marked in P1 and P2 plots.



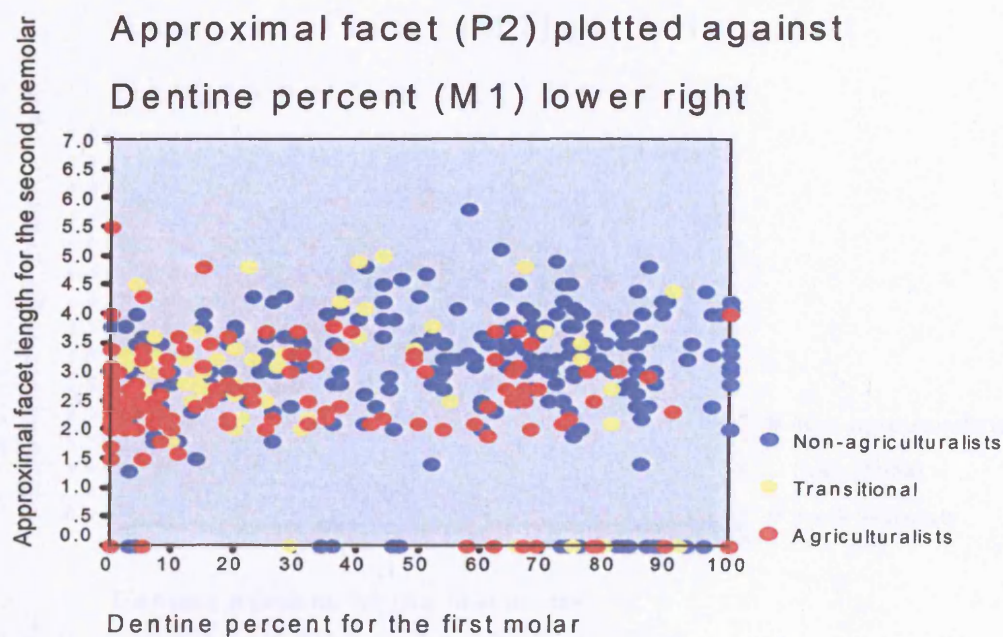


Figure 7.58: Scatter plot of the approximal facet length (mm) of lower right P2 plotted against occlusal wear (dentine percent for M1) for the different behaviour groups.

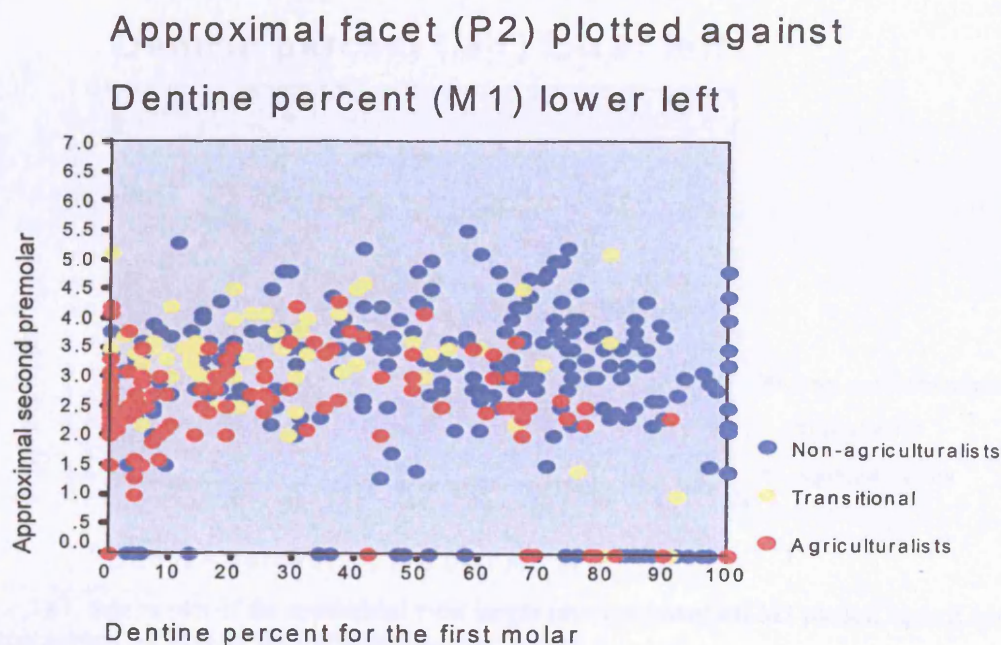


Figure 7.59: Scatter plot of the approximal facet length (mm) of lower left P2 plotted against occlusal wear (dentine percent for M1) for the different behaviour groups.

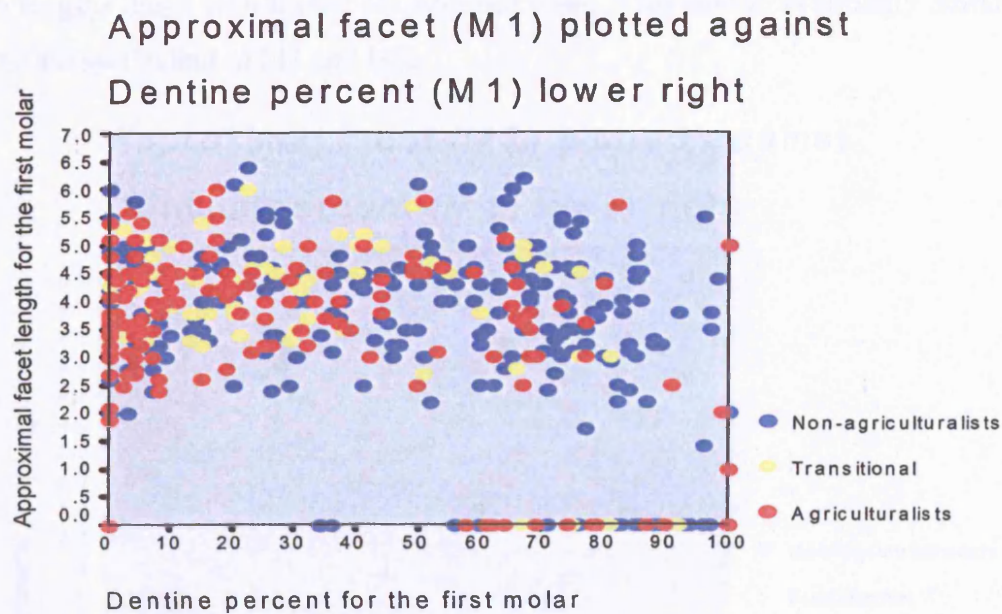


Figure 7.60: Scatter plot of the approximal facet length (mm) of lower right M1 plotted against occlusal wear (dentine percent for M1) for the different behaviour groups.

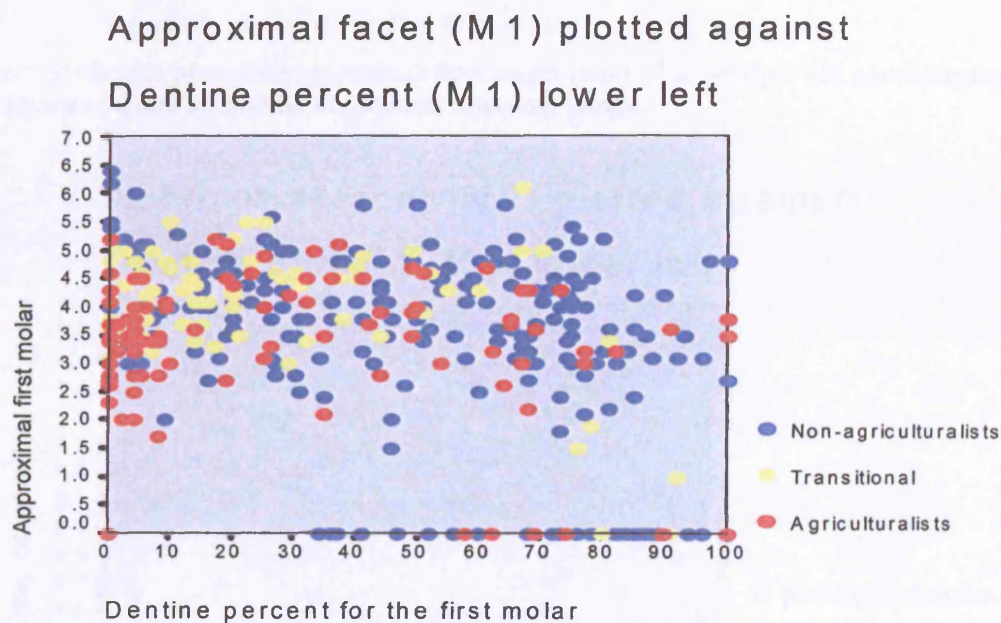


Figure 7.61: Scatter plot of the approximal facet length (mm) of lower left M1 plotted against occlusal wear (dentine percent for M1) for the different behaviour groups.

The scatter plots for M1, M2 and M3 (Figures 7.60 - 7.65) show even larger approximal wear facets than in the premolar teeth. They also show an even larger spread of values. There is some trend for the non-agriculturalists to show longer approximal wear facets in the higher grades of M1 occlusal wear than the transitionals and agriculturalists but the overlap is so great that this is not marked. In addition, the scatter of points describes an inverse curve, starting with lower approximal facet lengths with lower M1 occlusal wear, rising to larger approximal facet lengths with 50% M1 occlusal wear then the approximal



facet lengths drops with higher M1 occlusal wear. This pattern is strongly marked in M2 and to a lesser extent in M1 and M3.

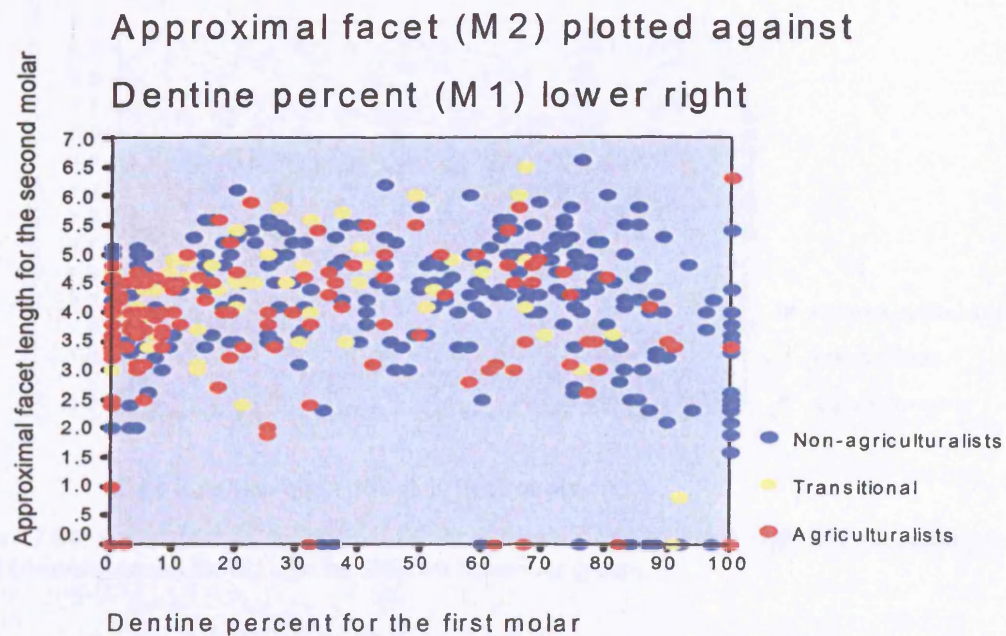


Figure 7.62: Scatter plot of the approximal facet length (mm) of lower right M2 plotted against occlusal wear (dentine percent for M1) for the different behaviour groups.

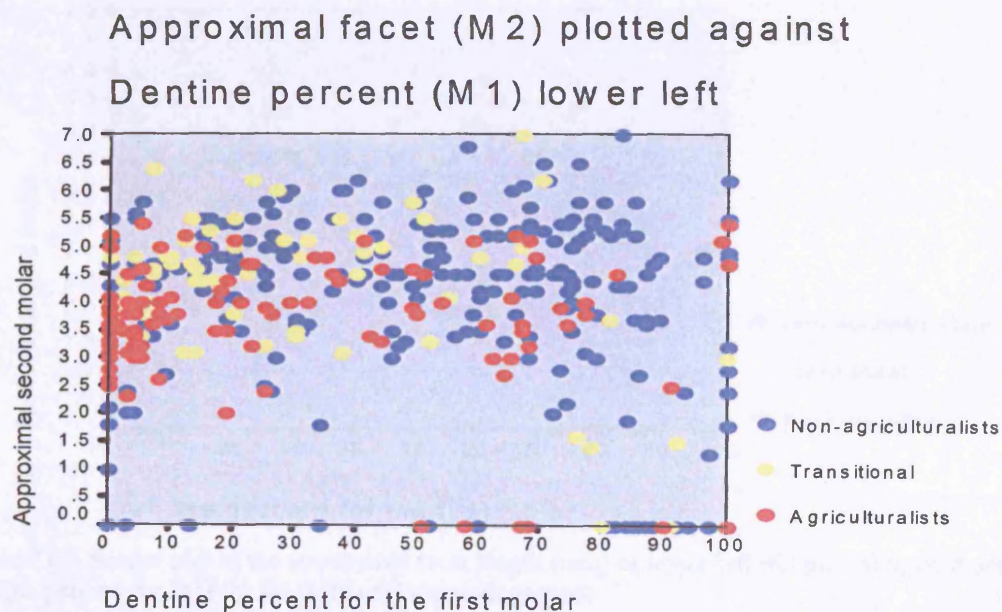


Figure 7.63: Scatter plot of the approximal facet length (mm) of lower left M2 plotted against occlusal wear (dentine percent for M1) for the different behaviour groups.

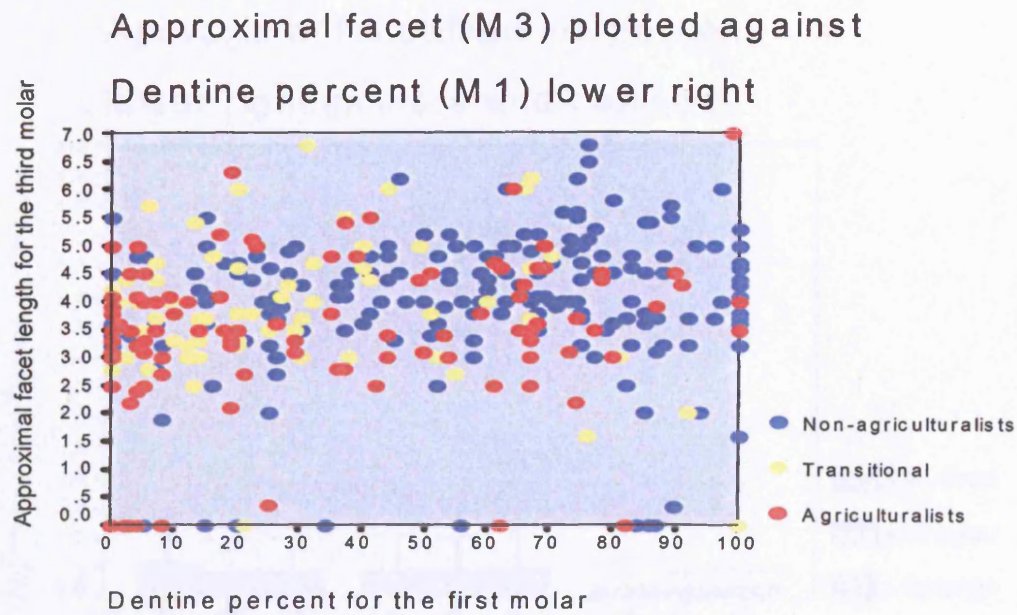


Figure 7.64: Scatter plot of the approximal facet length (mm) of lower right M3 plotted against occlusal wear (dentine percent for M1) for the different behaviour groups.

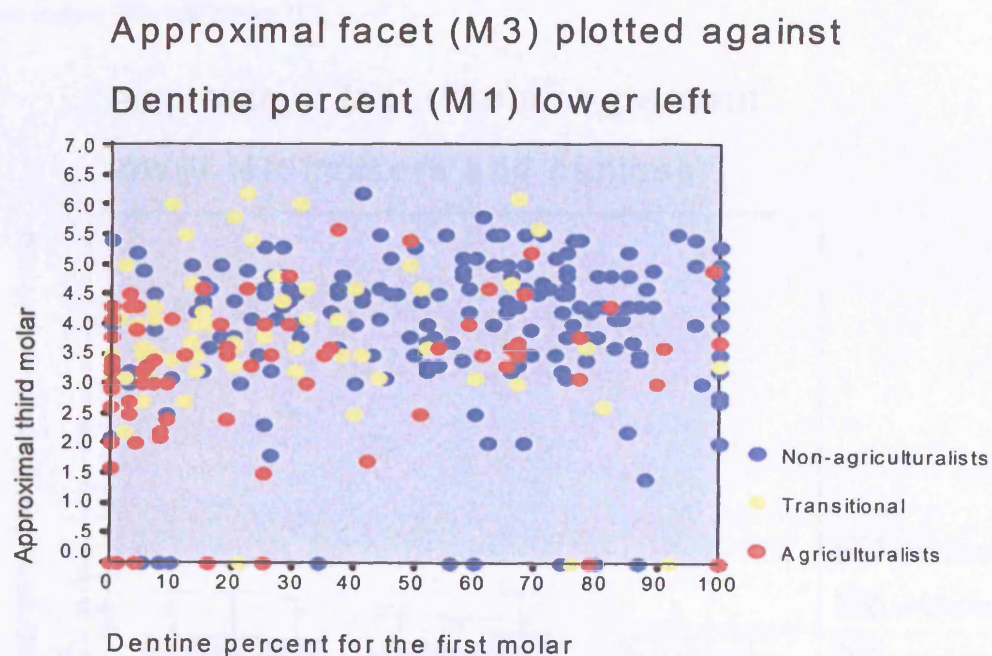


Figure 7.65: Scatter plot of the approximal facet length (mm) of lower left M3 plotted against occlusal wear (dentine percent for M1) for the different behaviour groups.



### Approximal facet/Dentine percent lower right incisors and canines

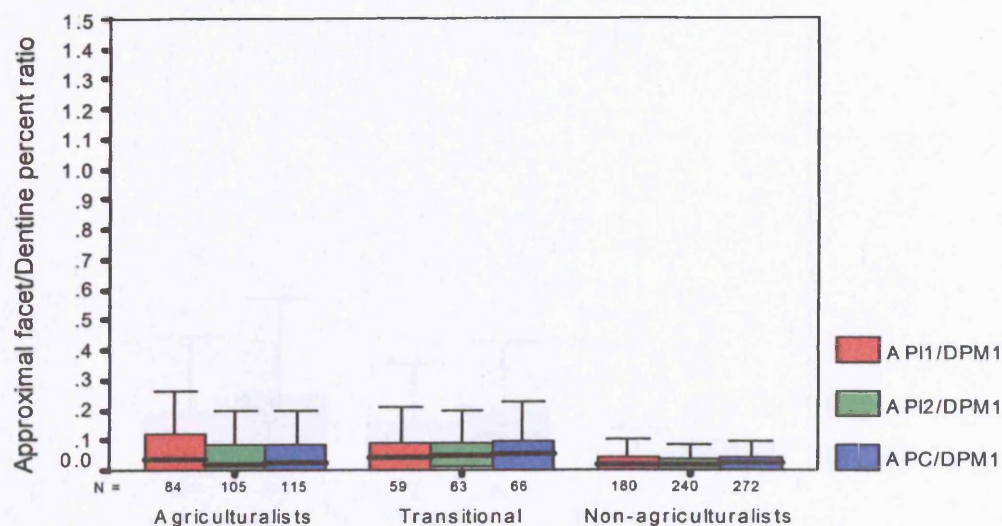


Figure 7.66: Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the full collection. Proportions are shown for the lower right first incisor (I1), second incisor (I2), and canine (C).

### Approximal facet/Dentine percent lower left incisors and canines

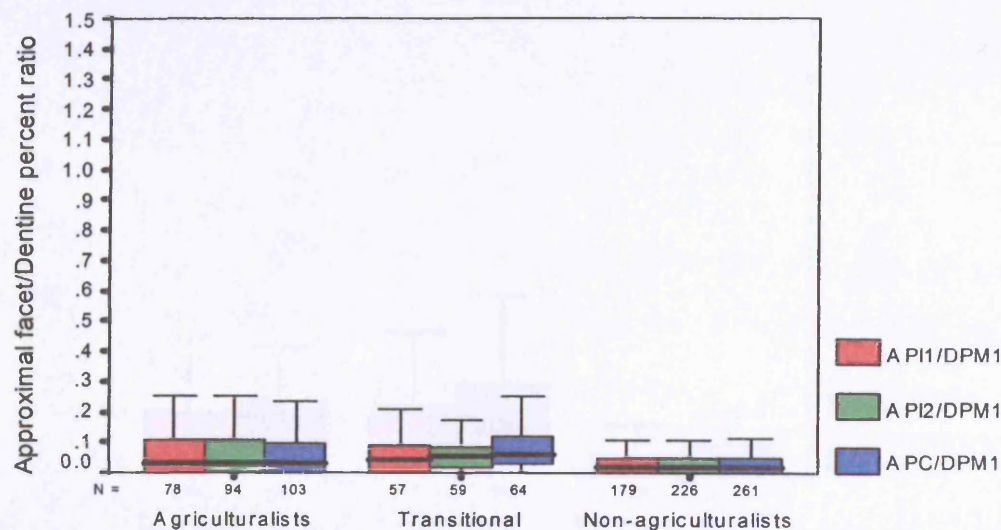


Figure 7.67: Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the full collection. Proportions are shown for the lower left first incisor (I1), second incisor (I2), and canine (C).

The box plot Figures 7.66 and 7.67 of the right-left anterior teeth show the interquartile ranges of all behavioural groups overlap but the non-agriculturalists have smaller interquartile ranges and smaller median approximal facet ratios. This same trend is also visible in the premolars (Figures 7.68 and 7.69) but is more marked. In addition the transitionals have slightly higher medians than the agriculturalists.



### Approximal facet/Dentine percent lower right premolars

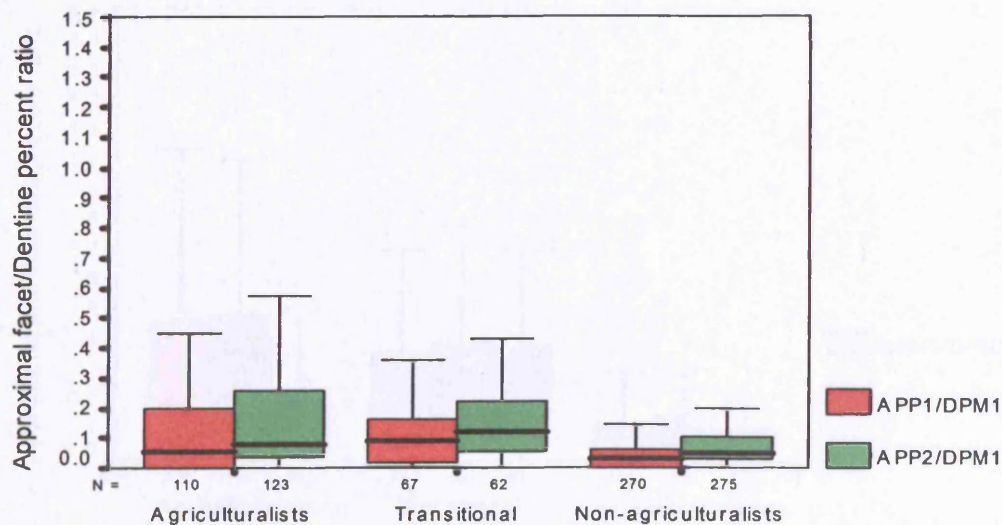


Figure 7.68: Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the full collection. Proportions are shown for the lower right first and second premolars (P1 and P2).

### Approximal facet/Dentine percent lower left premolars

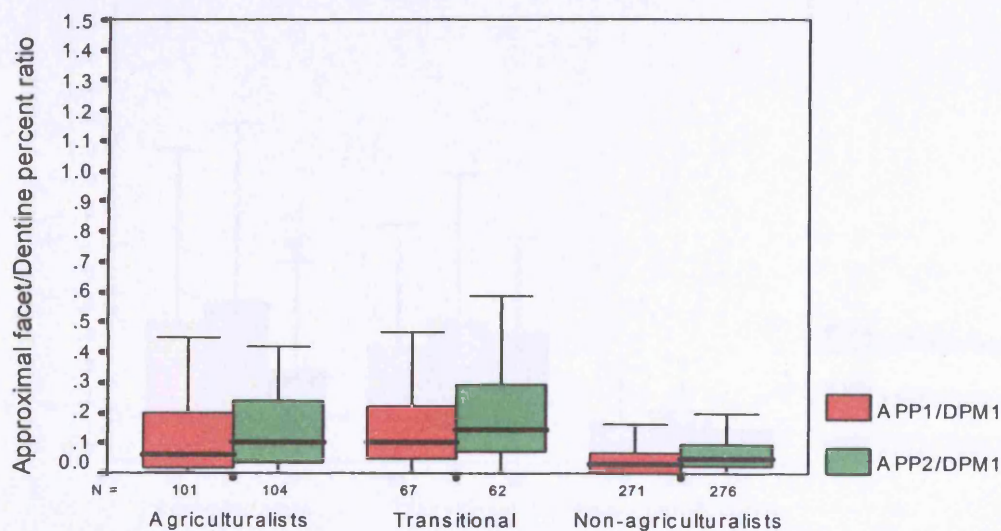


Figure 7.69: Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the full collection. Proportions are shown for the lower left first and second premolars (P1 and P2).

### Approximal facet/Dentine percent lower right molars

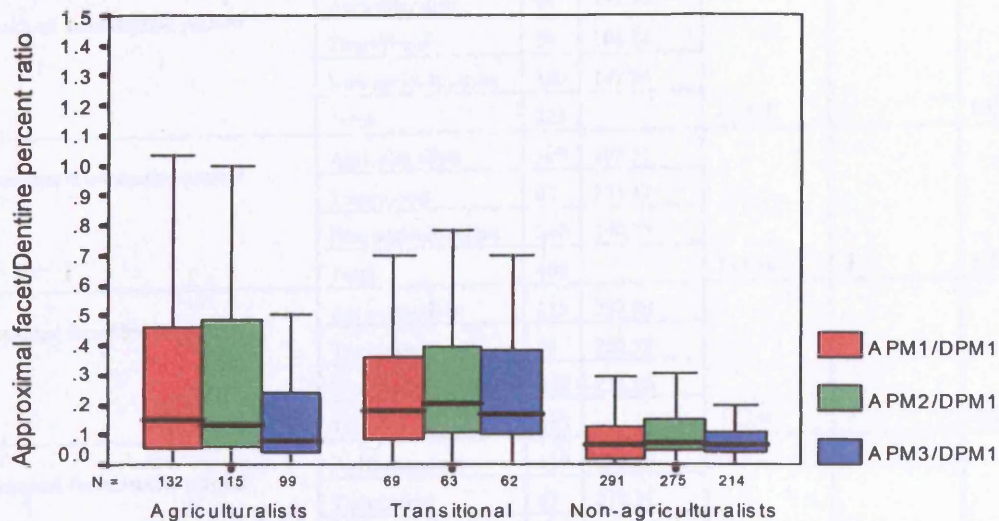


Figure 7.70: Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the full collection. Proportions are shown for the lower right first, second and third molars (M1, M2 and M3).

### Approximal facet/Dentine percent lower left molars

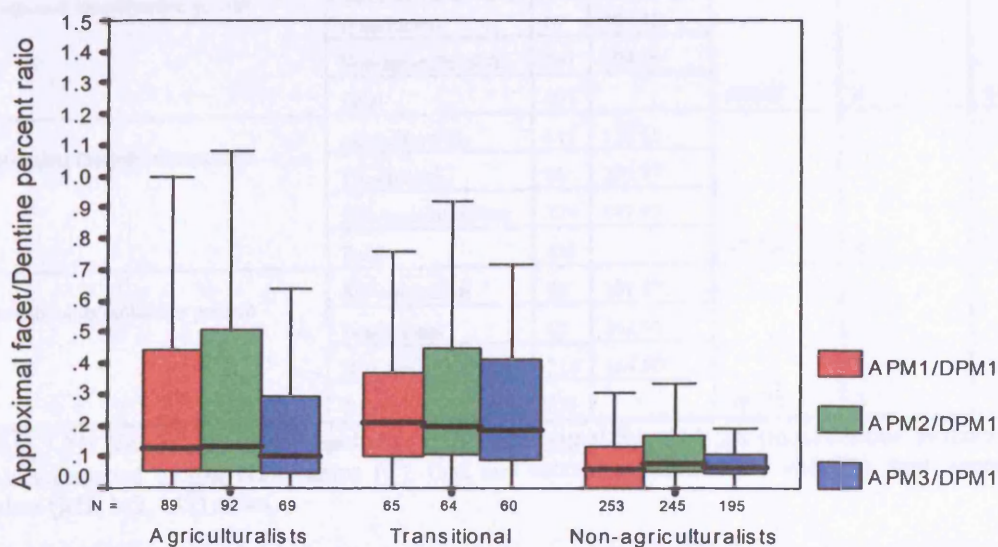


Figure 7.71: Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the full collection. Proportions are shown for the lower left first, second and third molars (M1, M2 and M3).

The trends seen in the premolars are even more marked in the molars (Figures 7.70 and 7.71), with lowest medians and smallest interquartile ranges in non-agriculturalists. Both transitionals and agriculturalists have large interquartile ranges but the median values are higher for the transitionals than for the agriculturalists.

## Kruskal-Wallis lower right

	BEHAVIOURAL GROUP	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/dentine percent I1	Agriculturalists	84	175.20	10.261	2	0.006
	Transitional	59	186.34			
	Non-agriculturalists	180	147.86			
	Total	323				
Approximal facet/dentine percent I2	Agriculturalists	105	205.51	15.938	2	0.000
	Transitional	63	255.17			
	Non-agriculturalists	240	190.75			
	Total	408				
Approximal facet/dentine percent C	Agriculturalists	115	232.49	17.146	2	0.000
	Transitional	66	282.72			
	Non-agriculturalists	272	211.16			
	Total	453				
Approximal facet/dentine percent P1	Agriculturalists	110	253.85	26.866	2	0.000
	Transitional	67	274.75			
	Non-agriculturalists	270	199.25			
	Total	447				
Approximal facet/dentine percent P2	Agriculturalists	123	255.89	27.928	2	0.000
	Transitional	62	292.10			
	Non-agriculturalists	275	205.25			
	Total	460				
Approximal facet/dentine percent M1	Agriculturalists	132	296.95	49.663	2	0.000
	Transitional	69	307.36			
	Non-agriculturalists	291	209.19			
	Total	492				
Approximal facet/dentine percent M2	Agriculturalists	115	258.65	37.786	2	0.000
	Transitional	63	295.97			
	Non-agriculturalists	275	197.97			
	Total	453				
Approximal facet/dentine percent M3	Agriculturalists	99	191.67	39.751	2	0.000
	Transitional	62	262.91			
	Non-agriculturalists	214	164.60			
	Total	375				

Table 7.21: Kruskal-Wallis of the lower right approximal facet length (mm)/dentine percent for the first (I1) and second incisor (I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2, M3) ratios.

**Kruskal-Wallis lower left**

	BEHAVIOURAL GROUP	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/dentine percent I1	Agriculturalists	78	167.03	8.837	2	0.012
	Transitional	57	182.68			
	Non-agriculturalists	179	145.33			
	Total	314				
Approximal facet/dentine percent I2	Agriculturalists	94	200.36	15.164	2	0.001
	Transitional	59	232.81			
	Non-agriculturalists	226	174.52			
	Total	379				
Approximal facet/dentine percent C	Agriculturalists	103	228.39	26.009	2	0.000
	Transitional	64	276.11			
	Non-agriculturalists	261	193.91			
	Total	428				
Approximal facet/dentine percent P1	Agriculturalists	101	255.07	41.916	2	0.000
	Transitional	67	286.31			
	Non-agriculturalists	271	190.53			
	Total	439				
Approximal facet/dentine percent P2	Agriculturalists	104	256.07	50.901	2	0.000
	Transitional	62	304.23			
	Non-agriculturalists	276	189.89			
	Total	442				
Approximal facet/dentine percent M1	Agriculturalists	89	234.73	46.982	2	0.000
	Transitional	65	276.46			
	Non-agriculturalists	253	174.57			
	Total	407				
Approximal facet/dentine percent M2	Agriculturalists	92	227.29	33.288	2	0.000
	Transitional	64	260.33			
	Non-agriculturalists	245	175.63			
	Total	401				
Approximal facet/dentine percent M3	Agriculturalists	69	176.20	34.873	2	0.000
	Transitional	60	219.49			
	Non-agriculturalists	195	140.12			
	Total	324				

Table 7:22: Kruskal-Wallis of the lower left approximal facet length (mm)/dentine percent for the first (I1) and second incisor (I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2, M3) ratios.

The Kruskal-Wallis tests (Tables 7.21 and 7.22) show that, even though these differences are small they are still statistically significant.

### Occlusal angle measurements



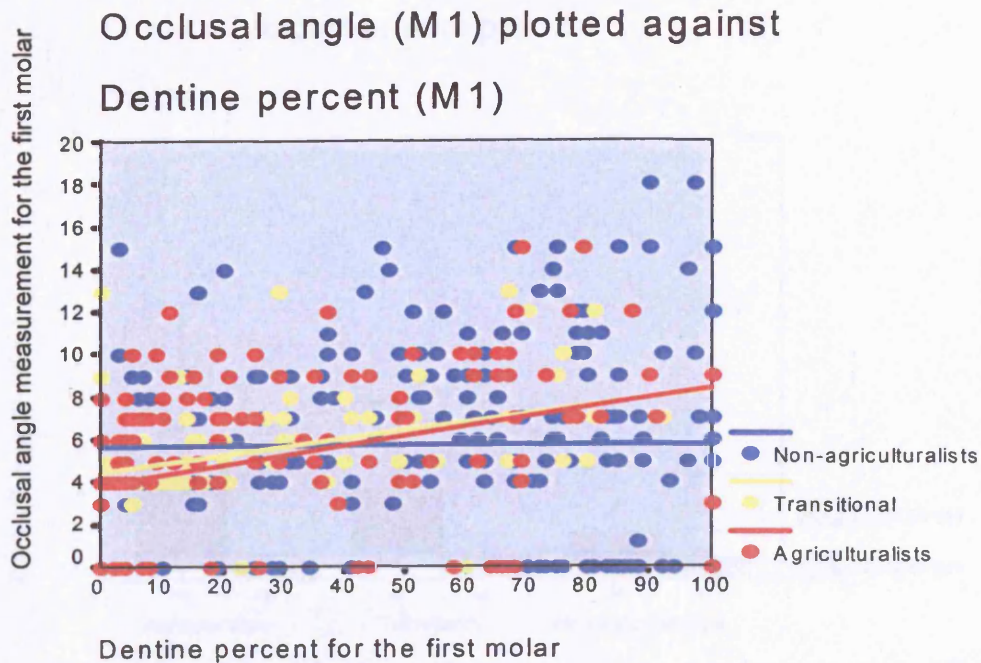


Figure 7.72: Scatter plot of the M1 occlusal angle plotted against M1 occlusal wear (dentine percent), for different behavioural groups.

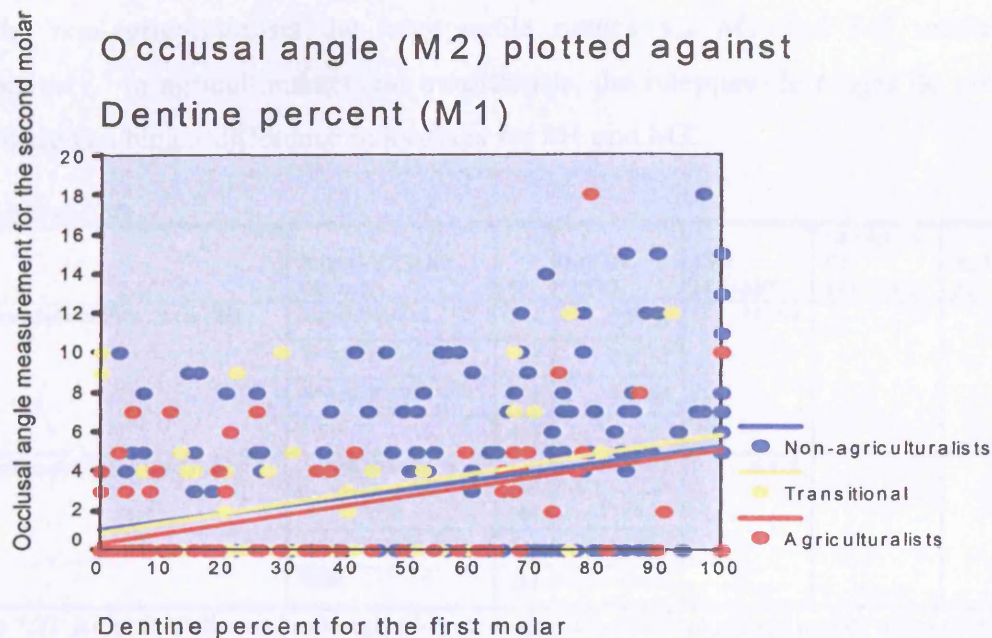


Figure 7.73: Scatter plot of the M2 occlusal angle plotted against M1 occlusal wear (dentine percent), for different behavioural groups.

The scatter plots of M1 and M2 occlusal angle measurement plotted against M1 dentine percent (Figures 7.72 and 7.73) show overlap of the scatter points, but with some variation between the collections. In general, the occlusal angle increases with occlusal wear. The transitional group rises more steeply than the agriculturalists and non-agriculturalists in both graphs. In M1 graph, the non-agriculturalists scatter is almost horizontal.

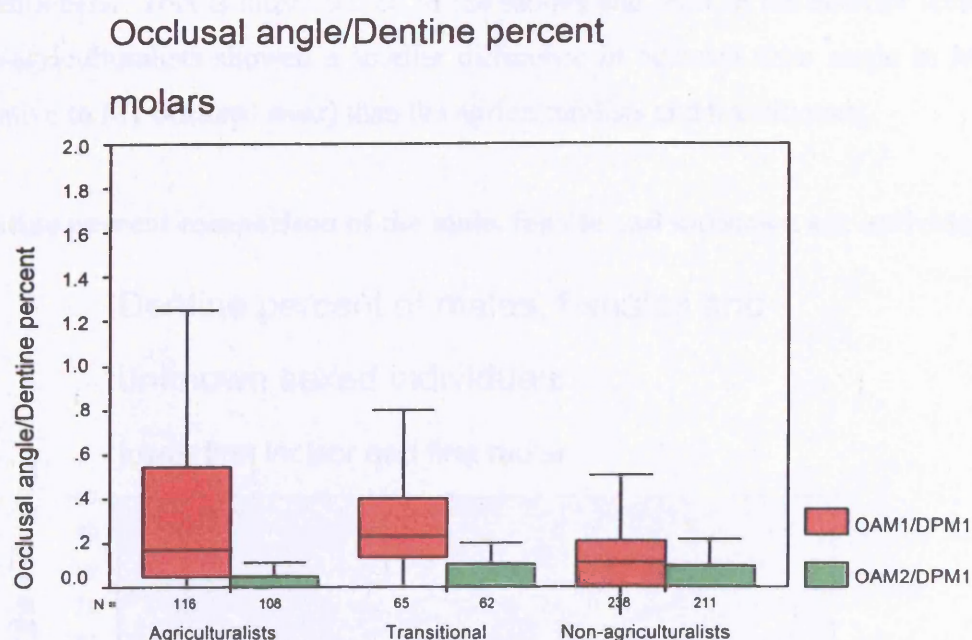


Figure 7.74: Box plots of the occlusal wear plane angle (OA), expressed as proportion of the first molar dentine percent (DPM1), for the full collection. Proportions are shown for the first and second molars (M1 and M2).

In the non-agriculturalists the interquartile ranges for M1 and M2 ratios overlap extensively. In agriculturalists and transitionals, the interquartile ranges do not overlap and there is a bigger difference in medians for M1 and M2.

#### Kruskal-Wallis tests

	BEHAVIOURAL GROUP	N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Occlusal angle/dentine percent M1	Agriculturalists	116	228.36	23.393	2	0.000
	Transitional	65	261.67			
	Non-agriculturalists	238	186.94			
	Total	419				
Occlusal angle/dentine percent M2	Agriculturalists	108	171.57	6.478	2	0.039
	Transitional	62	193.06			
	Non-agriculturalists	211	200.34			
	Total	381				

Table 7.23: Kruskal-Wallis occlusal angle (degrees) ratio of the first and second molars ratios (over dentine percent M1).

The Kruskal-Wallis test (Table 7.23) shows that the differences between the medians, as seen in the Figure 7.49, are statistically significant. Although in M2 there are only small differences in median values, the test is only just significant.

To summarise the comparison between the behavioural groups, the non-agriculturalists had less occlusal wear in I1, I2 and C relative to M1 than the agriculturalists and transitionals. This is also true to some extent of premolars, M2 and M3 occlusal wear relative to M1. In addition, the non-agriculturalists had smaller approximal wear facets, relative to M1 occlusal wear, than agriculturalists and



transitionals. This is most marked in the molars and least in the anterior teeth. Finally, non-agriculturalists showed a smaller difference in occlusal wear angle in M1 and M2 (relative to M1 occlusal wear) than the agriculturalists and transitionals.

#### Dentine percent comparison of the male, female and unknown sex individuals

##### Dentine percent of males, females and unknown sexed individuals

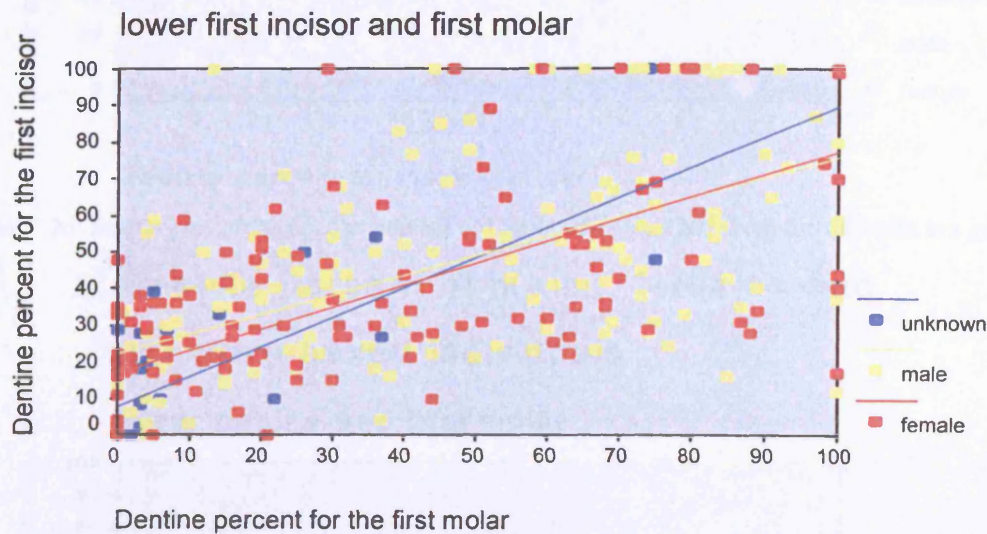


Figure 7.75: Scatter plot of the dentine percent of I1 plotted against M1 from the different sex groups.

Figures 7.75-7.77 shows that the scatters of points for the unknown sex, male and female groups overlap extensively, for I1, I2 and C. The trend lines show few differences either, so it is not possible that the different sexes have a different patterns of occlusal wear in anterior teeth.

## Dentine percent of males, females and unknown sexed individuals

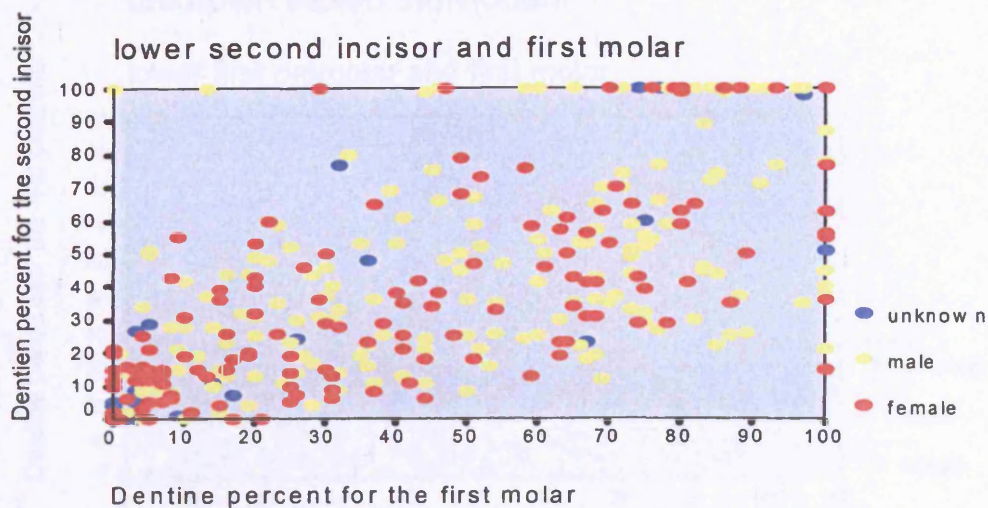


Figure 7.76: Scatter plot of the dentine percent of I2 plotted against M1 from the different sex groups.

## Dentine percent of males, females and unknown sexed individuals

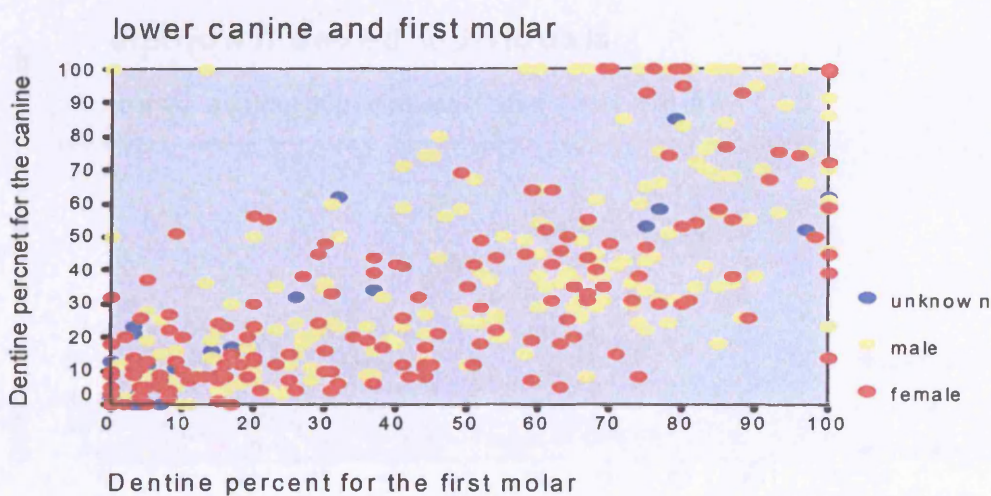


Figure 7.77: Scatter plot of the dentine percent of C plotted against M1 from the different sex groups.



### Dentine percent of males, females and unknown sexed individuals

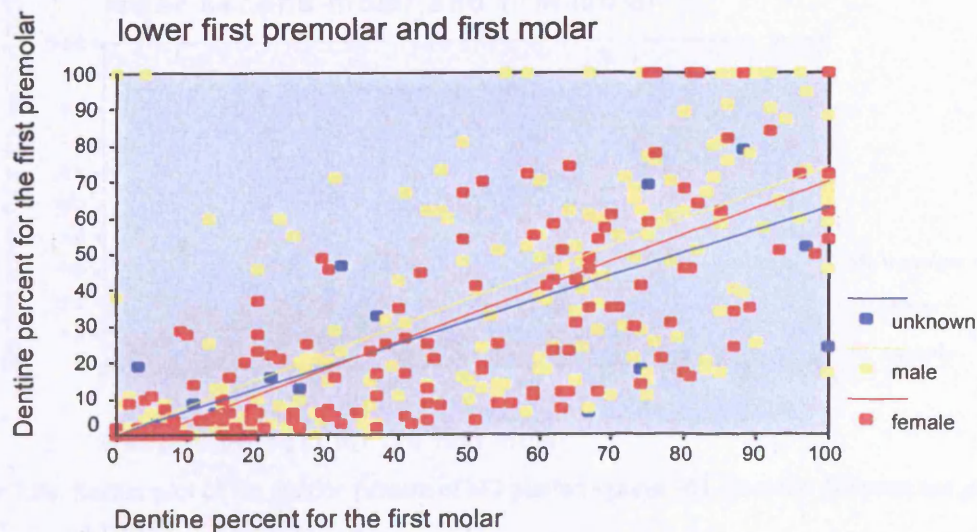


Figure 7.78: Scatter plot of the dentine percent of P1 plotted against M1 from the different sex groups.

### Dentine percent of males, females and unknown sexed individuals

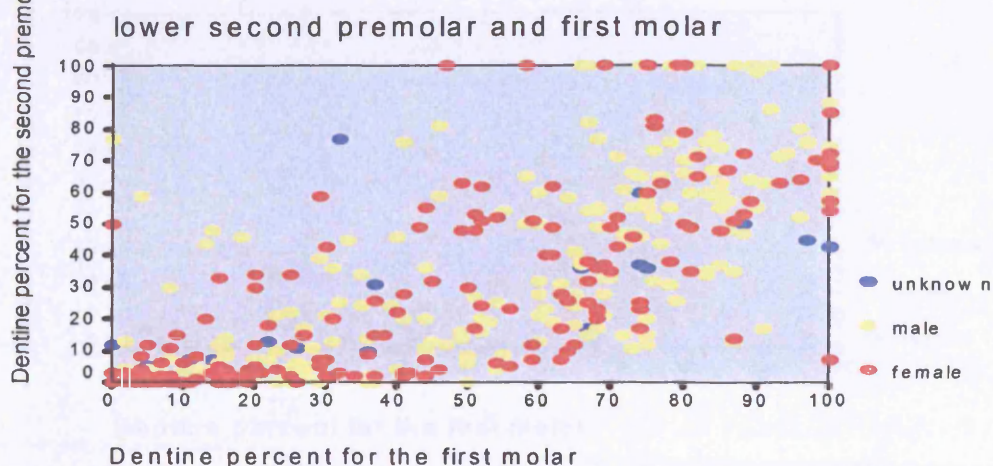


Figure 7.79: Scatter plot of the dentine percent of P2 plotted against M1 from the different sex groups.

Premolars (Figures 7.78 and 7.79) similarly show extensive overlap of scatters for the sexes, as do the molars (Figures 7.80 and 7.81). The dentine percent scatter plots therefore show little difference of occlusal wear for the males, females and unknown sexed individuals.

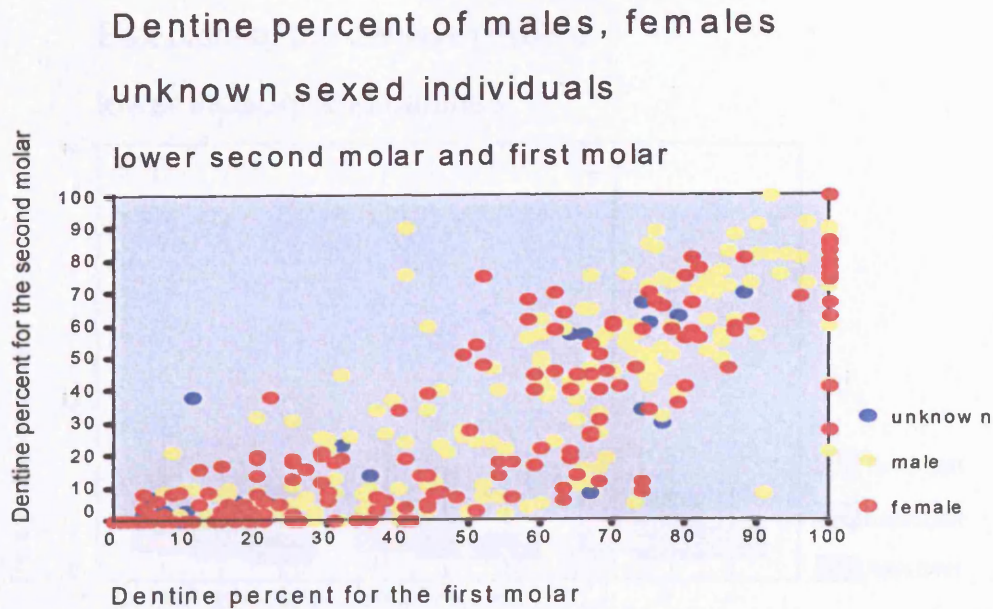


Figure 7.80: Scatter plot of the dentine percent of M2 plotted against M1 from the different sex groups.

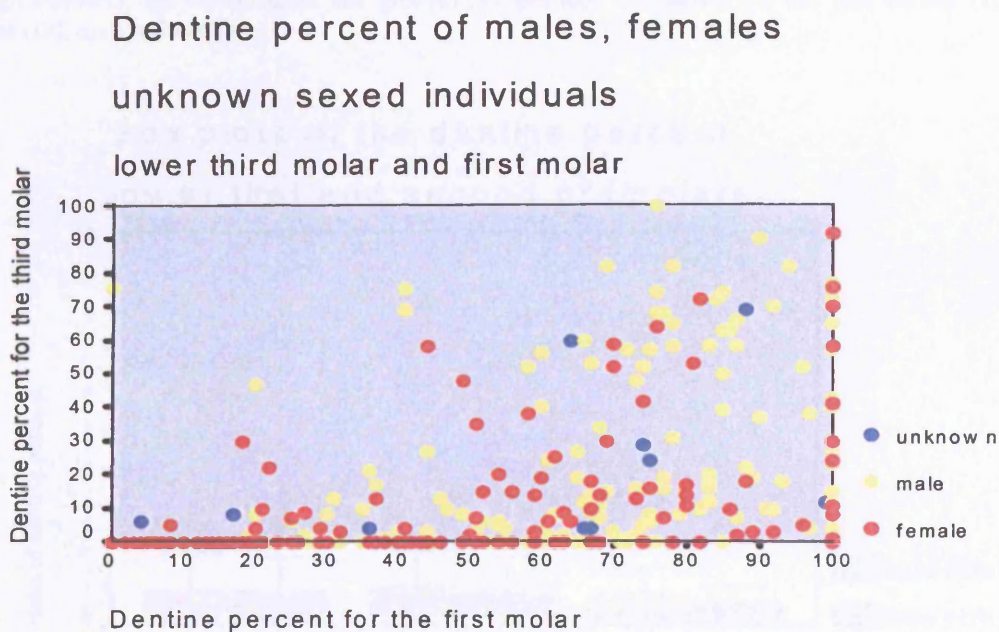


Figure 7.81: Scatter plot of the dentine percent of M3 plotted against M1 from the different sex groups.

As in Figure 7.45 (full collection) the interquartile and median ratios decrease from I1, to I2 to C (Figure 7.82 below). This pattern is repeated in the females, males and unknown sexed individuals, with very little difference between them. The interquartile is, however, greater in the unknown sex group than the female and male groups. The median ratio of I1 is slightly higher in the unknown sex assemblage but the male and female group have similar median values for all the anterior teeth. As with the scatter plots there is little evidence of a consistent difference of the sexes. The same is true for the box plots of the premolars (Figures 7.83) and molars (Figures 7.84).



## Box plots of the dentine percent

## lower incisors and canines

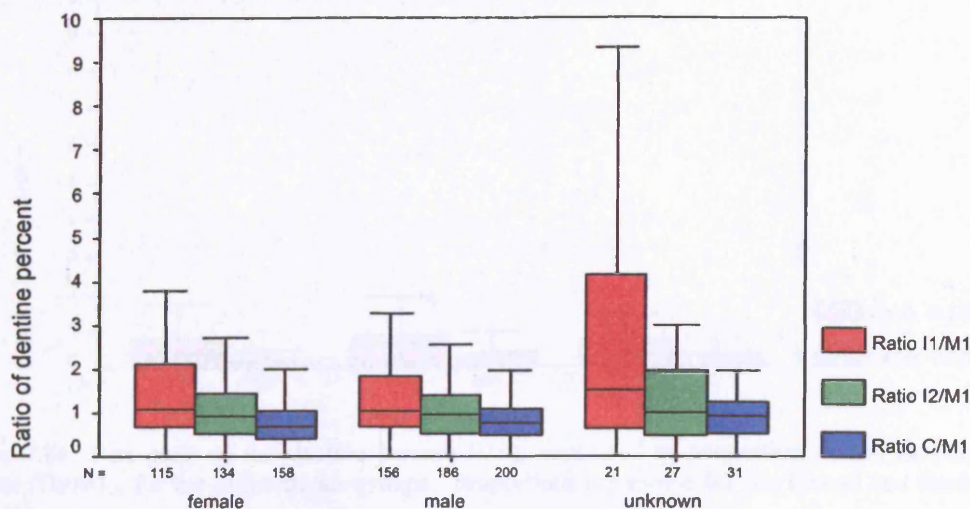


Figure 7.82: Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for the different sex groups. Proportions are shown for the first incisor (I1), second incisor (I2), and canine (C).

## Box plots of the dentine percent

## lower first and second premolars

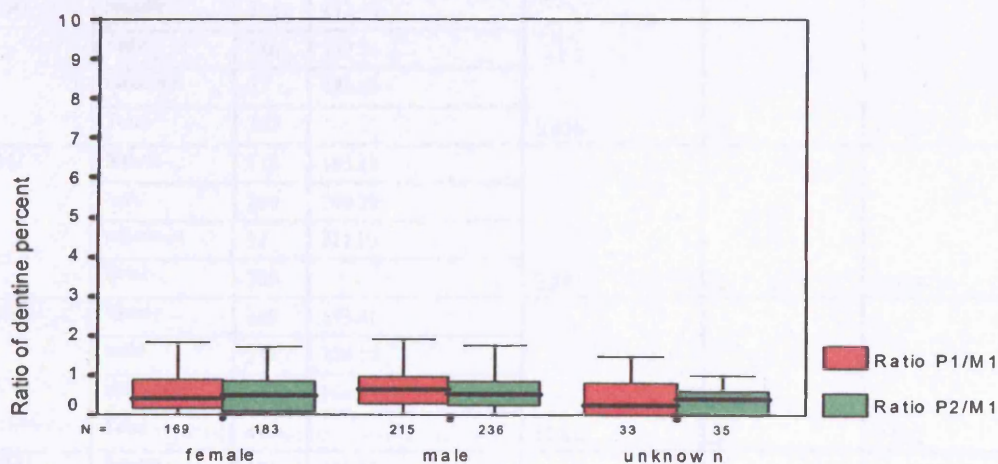


Figure 7.83: Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for the different sex groups. Proportions are shown for the first and second premolars (P1 and P2).

### Box plots of the dentine percent lower second and third molar

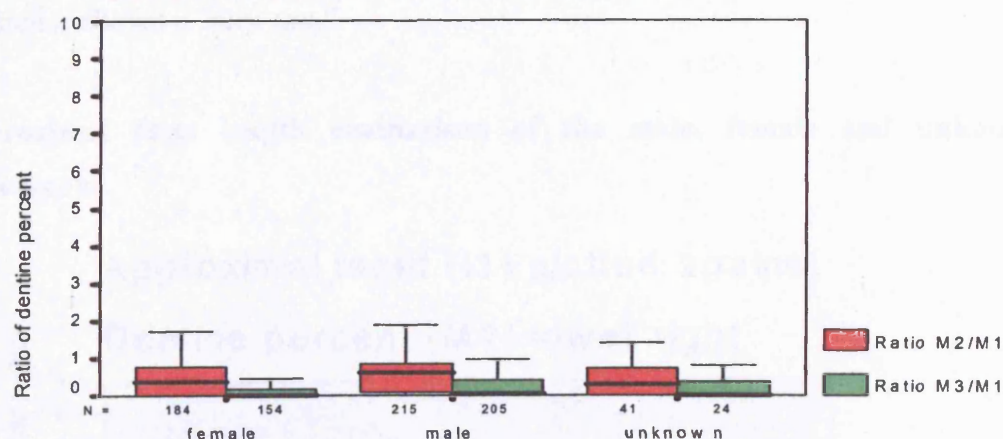


Figure 7.84: Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for the different sex groups. Proportions are shown for the second and third molars (M2 and M3).

#### Kruskal-Wallis

	SEX	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Ratio I1/M1	female	115	149.50	1.128	2	0.569
	male	156	142.36			
	unknown	21	160.86			
	Total	292				
Ratio I2/M1	female	134	173.54	0.636	2	0.727
	male	186	172.21			
	unknown	27	188.63			
	Total	347				
Ratio C/M1	female	158	185.16	2.283	2	0.319
	male	200	200.29			
	unknown	31	211.03			
	Total	389				
Ratio P1/M1	female	169	193.41	12.947	2	0.002
	male	215	228.19			
	unknown	33	163.85			
	Total	417				
Ratio P2/M1	female	183	221.33	5.737	2	0.057
	male	236	238.55			
	unknown	35	185.23			
	Total	454				
Ratio M2/M1	female	184	209.13	7.917	2	0.019
	male	215	236.65			
	unknown	41	186.87			
	Total	440				
Ratio M3/M1	female	154	172.84	9.498	2	0.009
	male	205	206.45			
	unknown	24	191.52			
	Total	383				

Table 7:24: Kruskal-Wallis test of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for the different sex groups. Proportions are shown for the full dental arcade.



The Kruskal-Wallis tests (Table 7.24) show no significant differences in dentine percent ratios for any teeth except for P1<sup>82</sup> and M3. Even in these teeth however, the actual difference shown is very small.

### Approximal facet length comparison of the male, female and unknown sex individuals

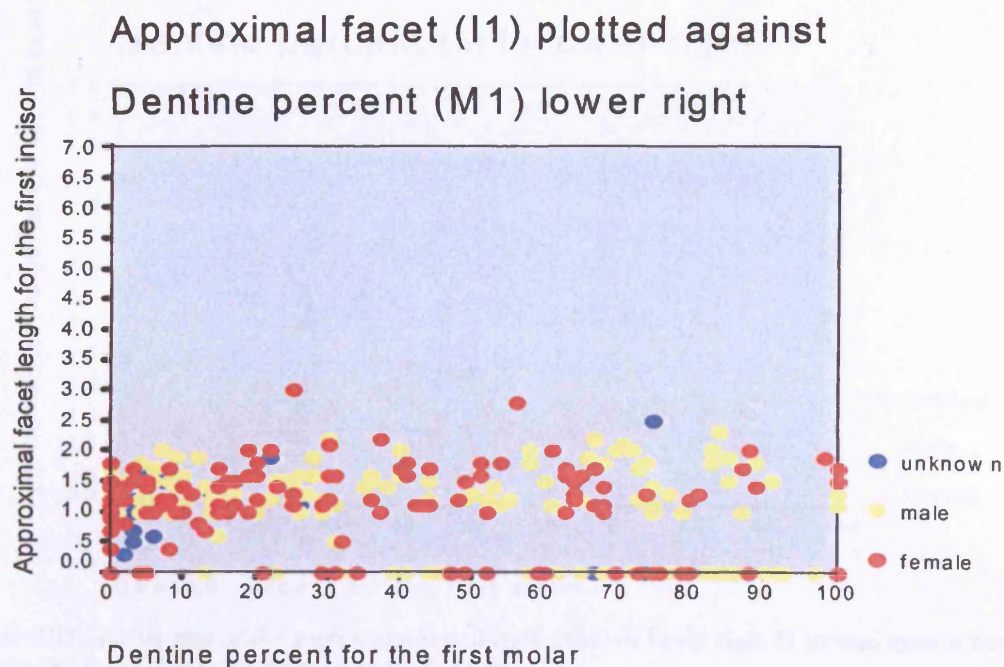


Figure 7.85: Scatter plot of the approximal facet length (mm) of lower right I1 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

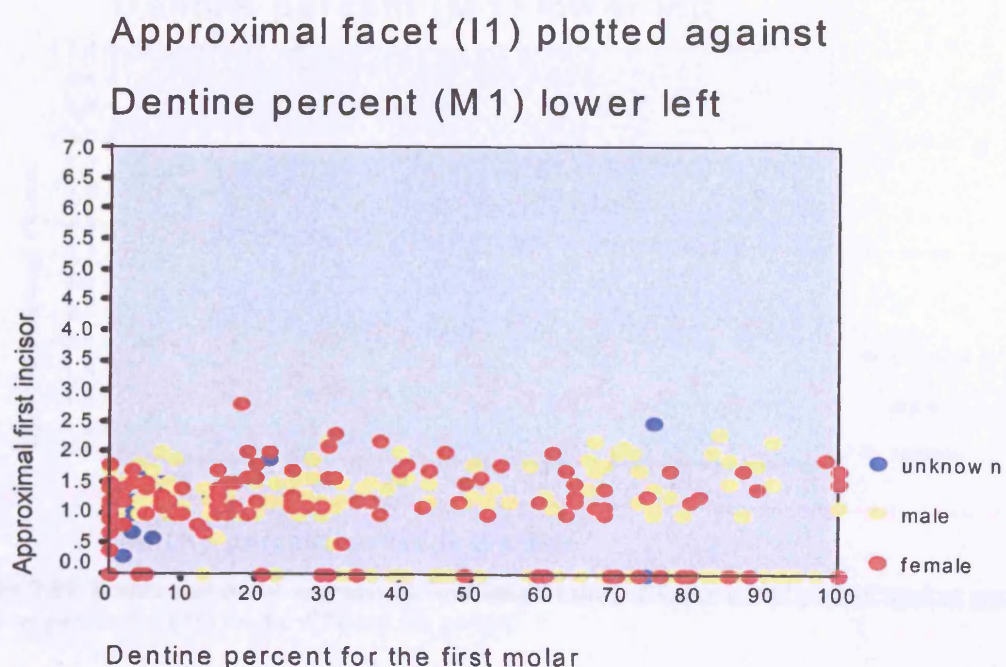


Figure 7.86: Scatter plot of the approximal facet length (mm) of lower left I1 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

Generally all scatter plots for the approximal facet length plotted against M1 occlusal wear (Figures 7.85-7.100) show a similar sequence of changes from incisors to canines, premolars and molars to that shown in the full collection (Figures 7.50-7.71). There is extensive overlap between male, female and unknown sexed scatters with little evidence of a different pattern of approximal wear.

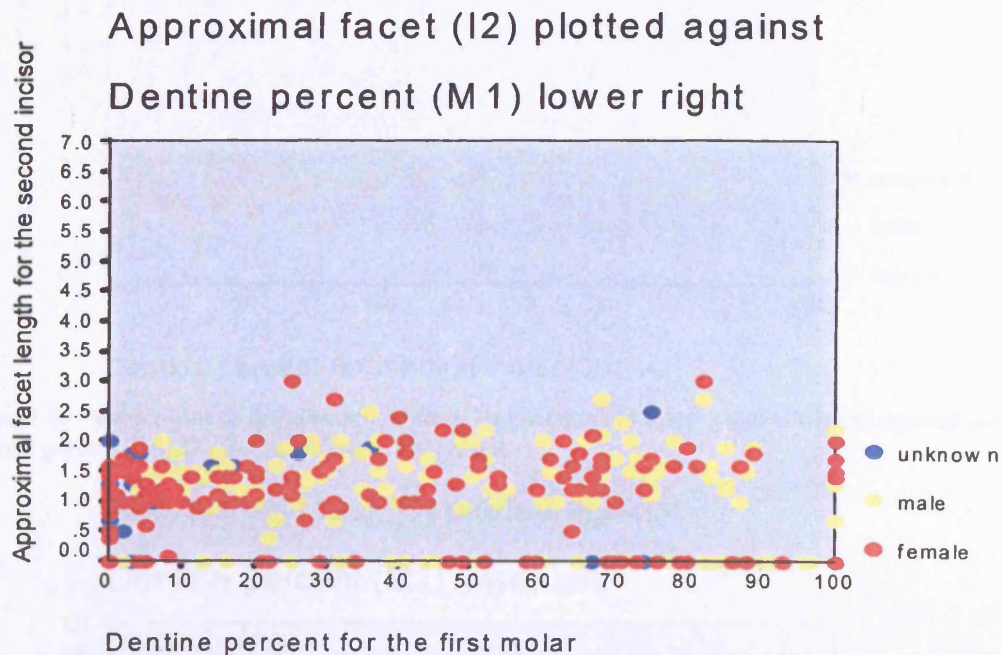


Figure 7.87: Scatter plot of the approximal facet length (mm) of lower right I2 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

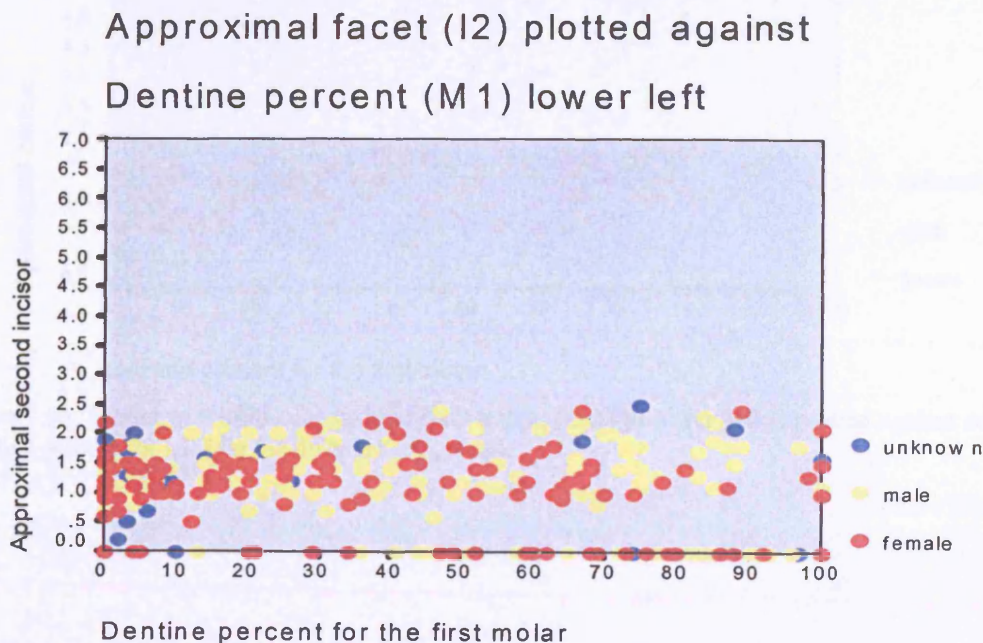


Figure 7.88: Scatter plot of the approximal facet length (mm) of lower left I2 plotted against occlusal wear (dentine percent for M1) for the different sex groups.



### Approximal facet (C) plotted against Dentine percent (M1) lower right

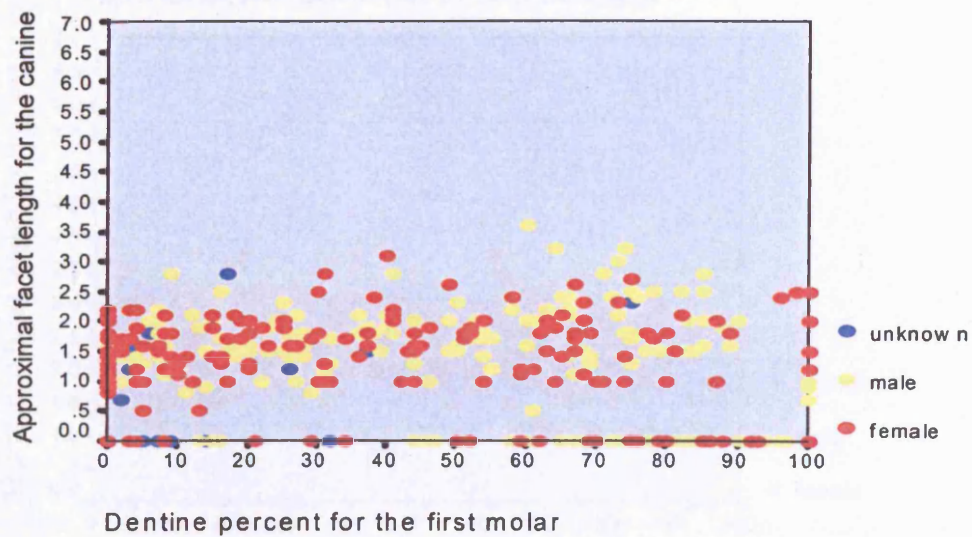


Figure 7.89: Scatter plot of the approximal facet length (mm) of lower right C plotted against occlusal wear (dentine percent for M1) for the different sex groups.

### Approximal facet (C) plotted against Dentine percent (M1) lower left

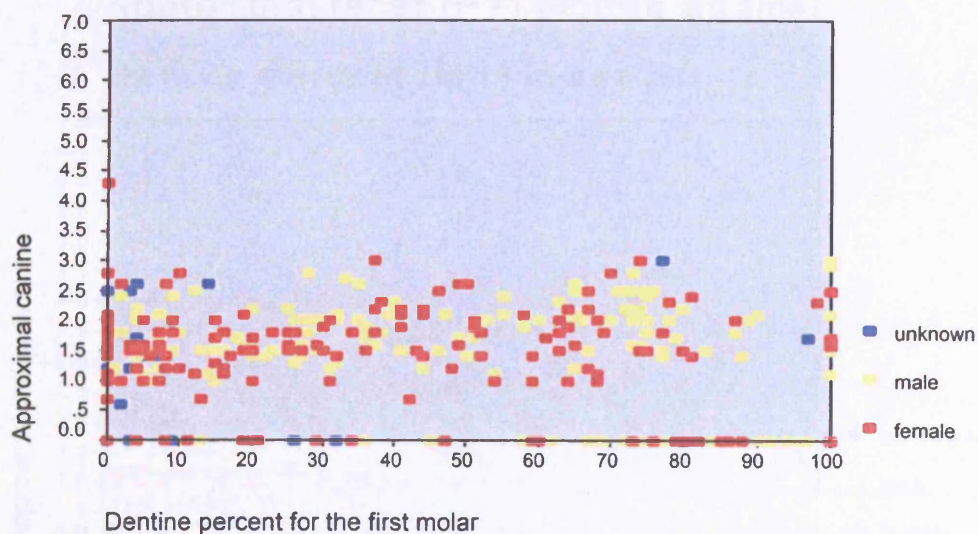


Figure 7.90: Scatter plot of the approximal facet length (mm) of lower left C plotted against occlusal wear (dentine percent for M1) for the different sex groups.

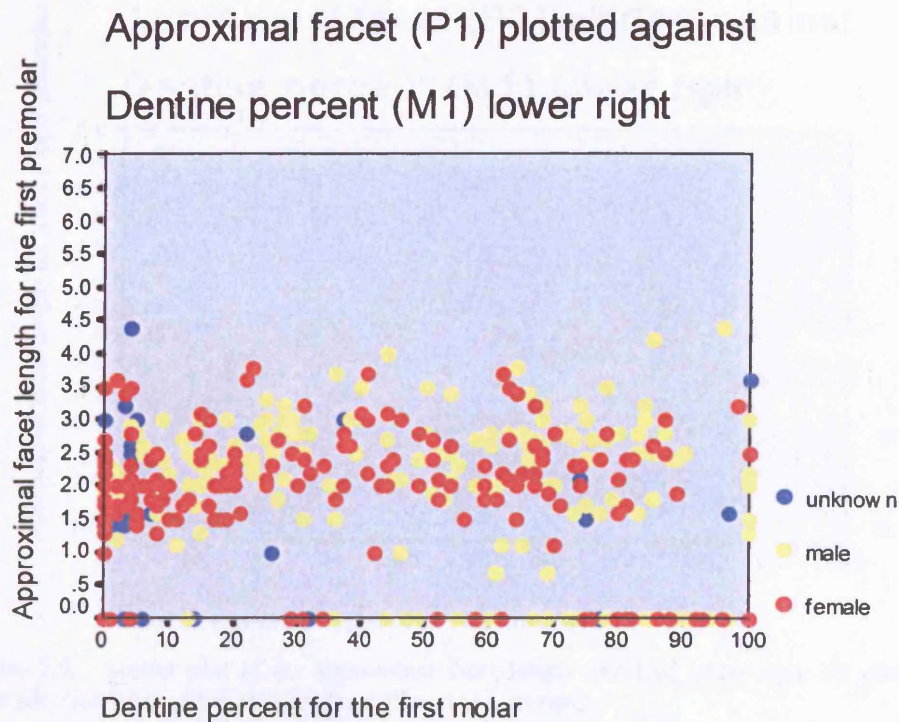


Figure 7.91: Scatter plot of the approximal facet length (mm) of lower right P1 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

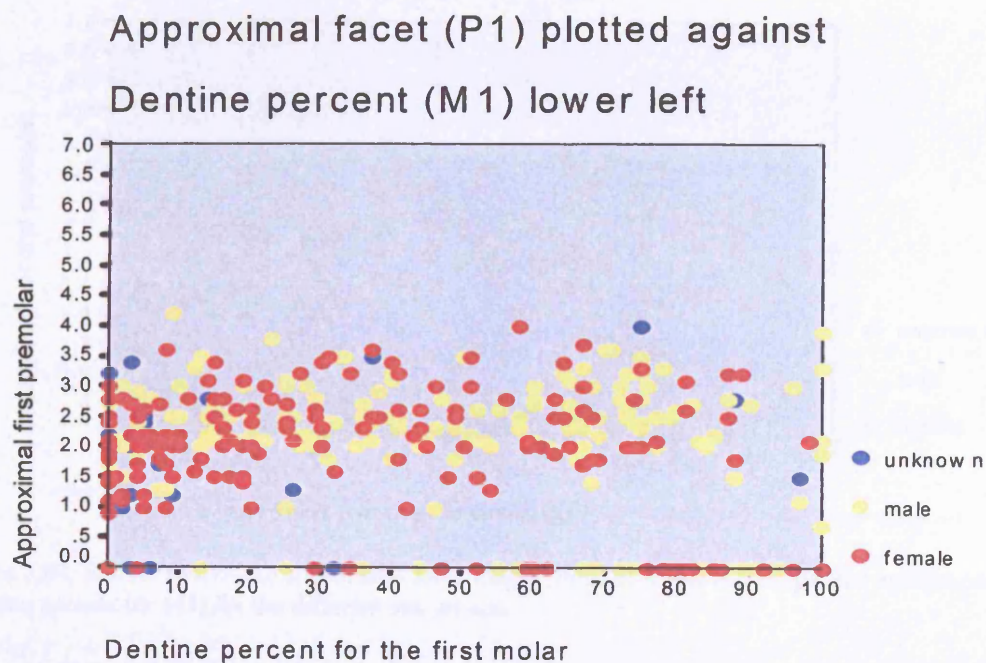


Figure 7.92: Scatter plot of the approximal facet length (mm) of lower left P1 plotted against occlusal wear (dentine percent for M1) for the different sex groups.



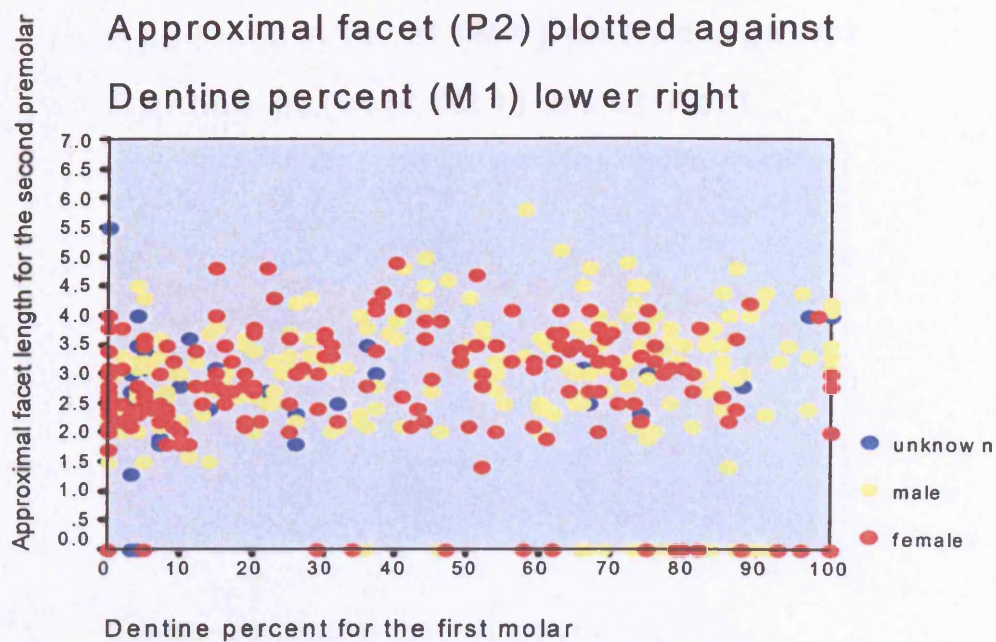


Figure 7.93: Scatter plot of the approximal facet length (mm) of lower right P2 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

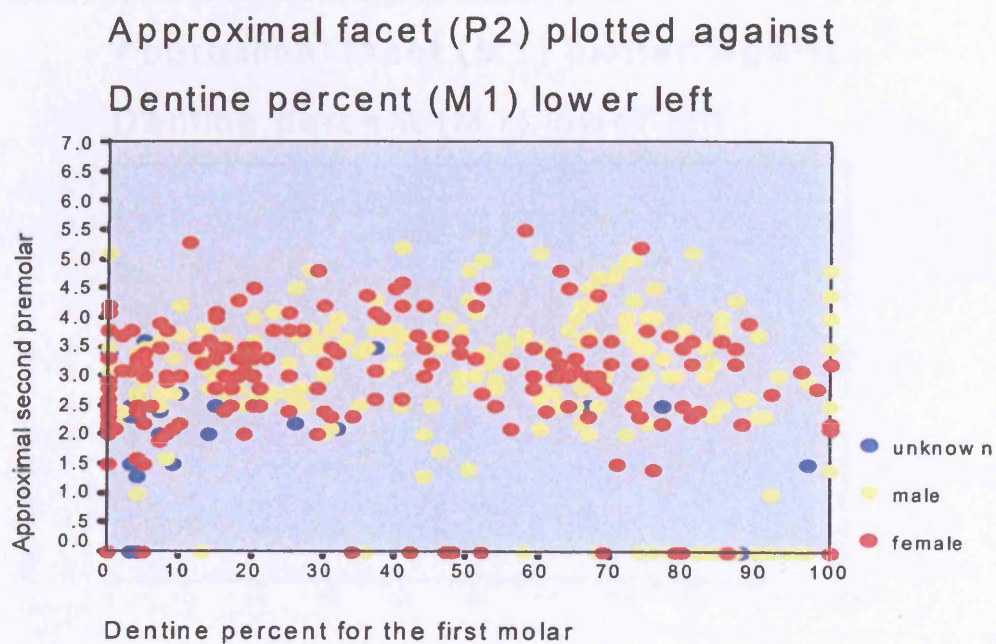


Figure 7.94: Scatter plot of the approximal facet length (mm) of lower left P2 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

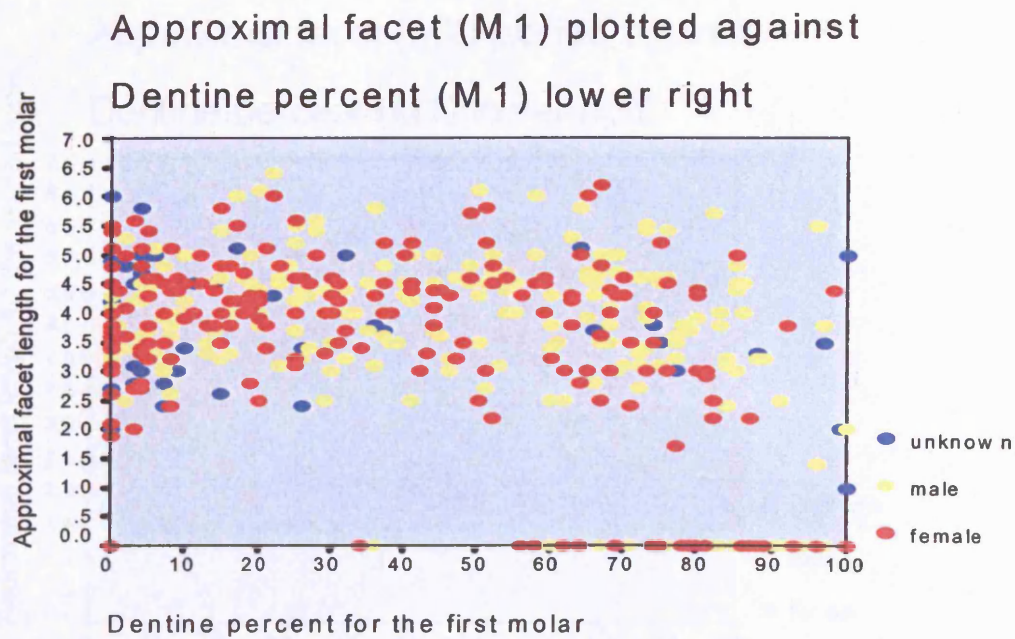


Figure 7.95: Scatter plot of the approximal facet length (mm) of lower right M1 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

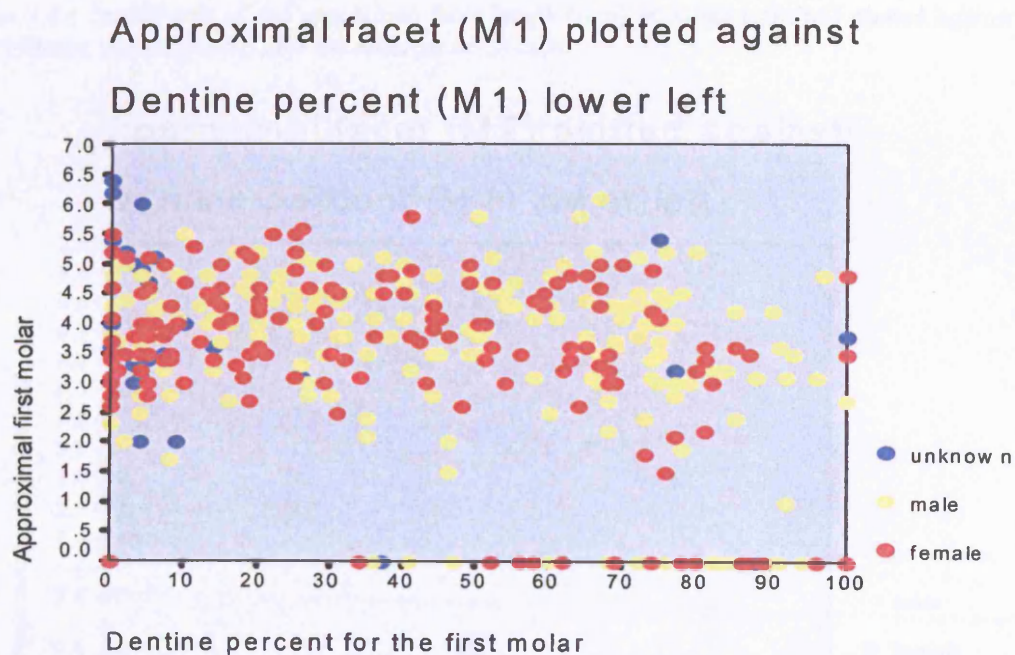


Figure 7.96: Scatter plot of the approximal facet length (mm) of lower left M1 plotted against occlusal wear (dentine percent for M1) for the different sex groups.



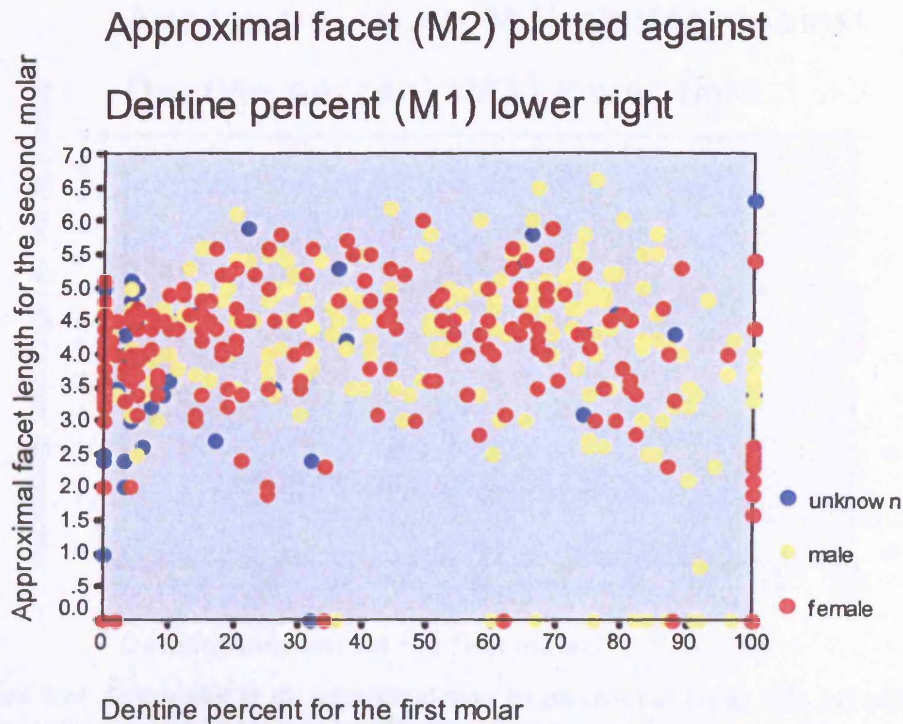


Figure 7.97: Scatter plot of the approximal facet length (mm) of lower right M2 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

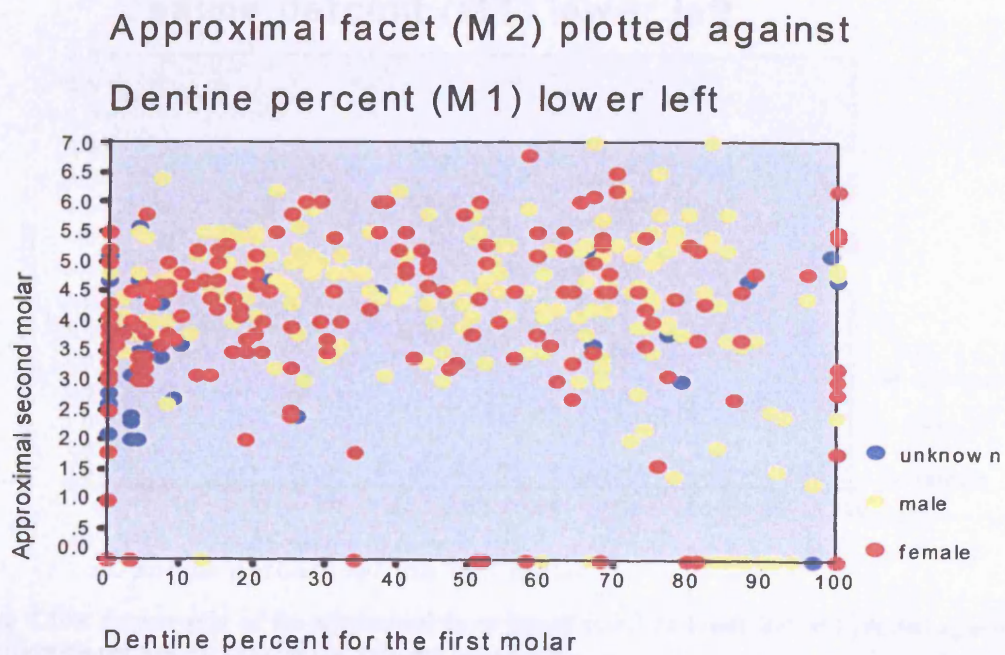


Figure 7.98: Scatter plot of the approximal facet length (mm) of lower left M2 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

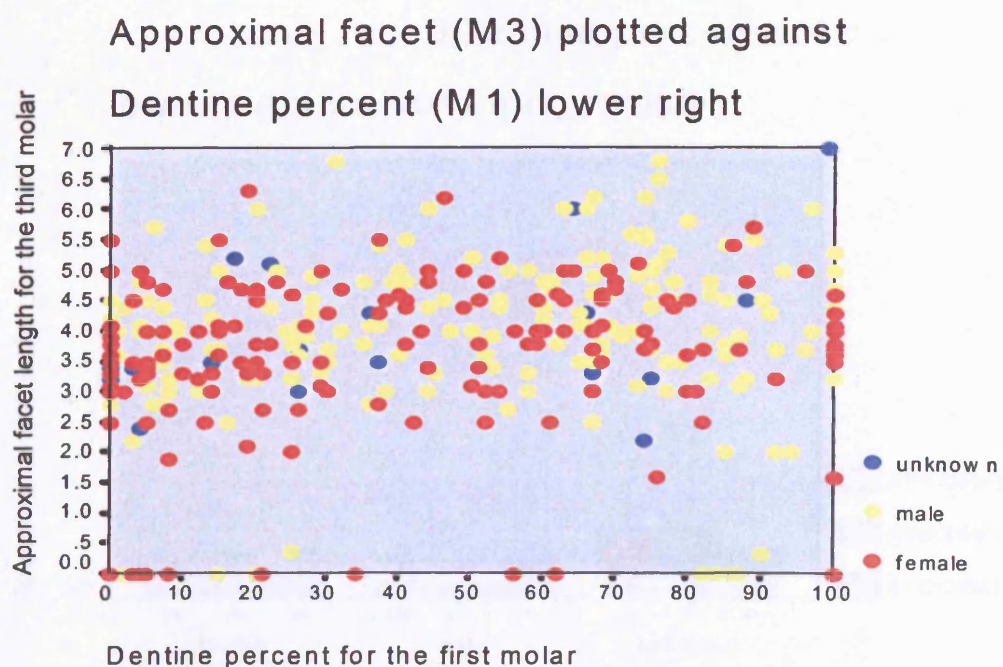


Figure 7.99: Scatter plot of the approximal facet length (mm) of lower right M3 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

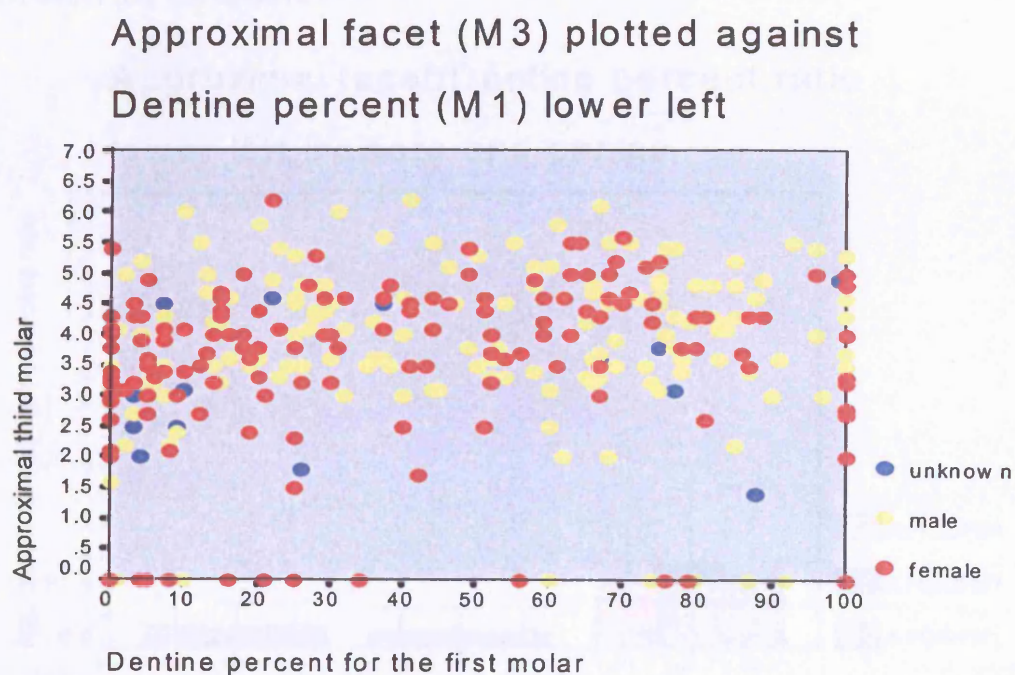


Figure 7.100: Scatter plot of the approximal facet length (mm) of lower left M3 plotted against occlusal wear (dentine percent for M1) for the different sex groups.



### Approximal facet/Dentine percent ratio lower right incisors and canine

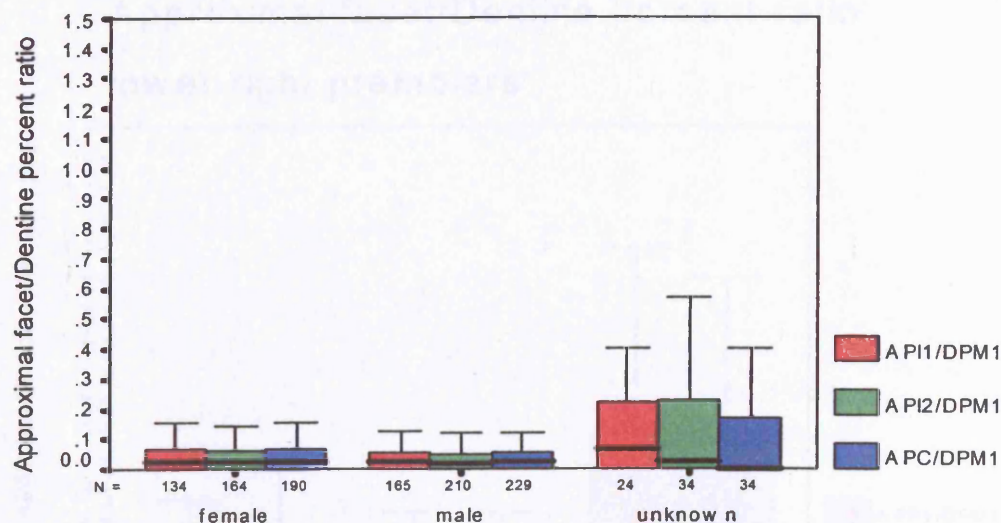


Figure 7.101: Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the sex groups. Proportions are shown for the lower right first incisor (I1), second incisor (I2), and canine (C).

### Approximal facet/Dentine percent ratio lower left incisors and canine

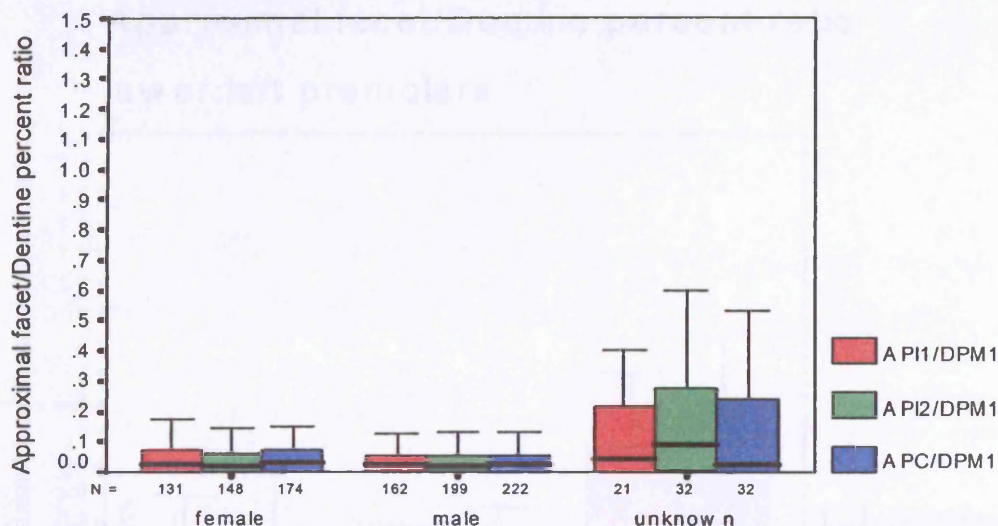


Figure 7.102: Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the sex groups. Proportions are shown for the lower left first incisor (I1), second incisor (I2), and canine (C).

The most striking thing about the box plots of approximal facet/dentine percent ratio (Figures 7.101-7.106) is the greater interquartile range and overall range of the unknown sexed group. This may be due to the smaller size of the group but must also represent the nature of the individuals included (see Chapter 8, Discussion). In incisors and canine there is very little difference between male and female groups. For premolars (Figures

7.103-7.104) and molars (Figures 7.105 And 7.106) the male and female medians are similar but the females have larger interquartile ranges and overall ranges than the males.

### Approximal facet/Dentine percent ratio

#### lower right premolars

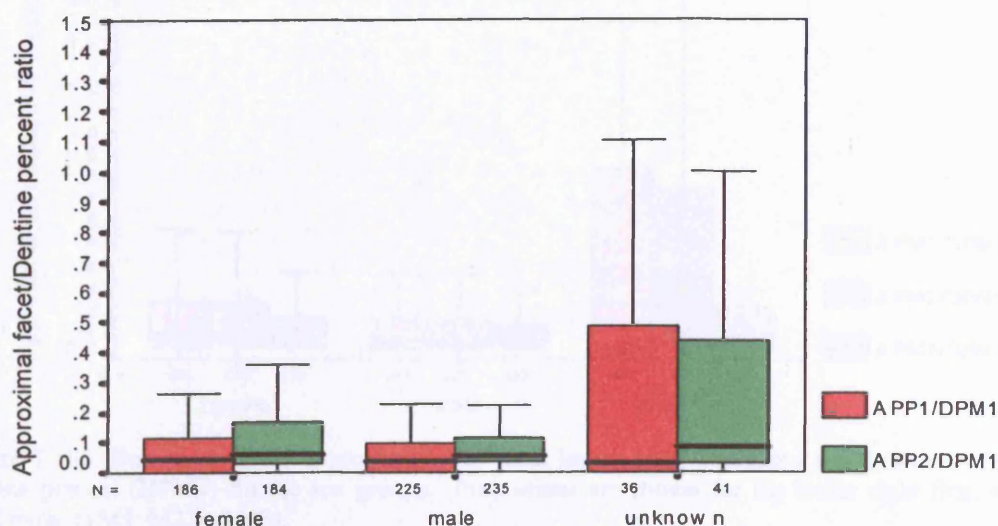


Figure 7.103: Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the sex groups. Proportions are shown for the lower right first and second premolars (P1 and P2).

### Approximal facet/Dentine percent ratio

#### lower left premolars

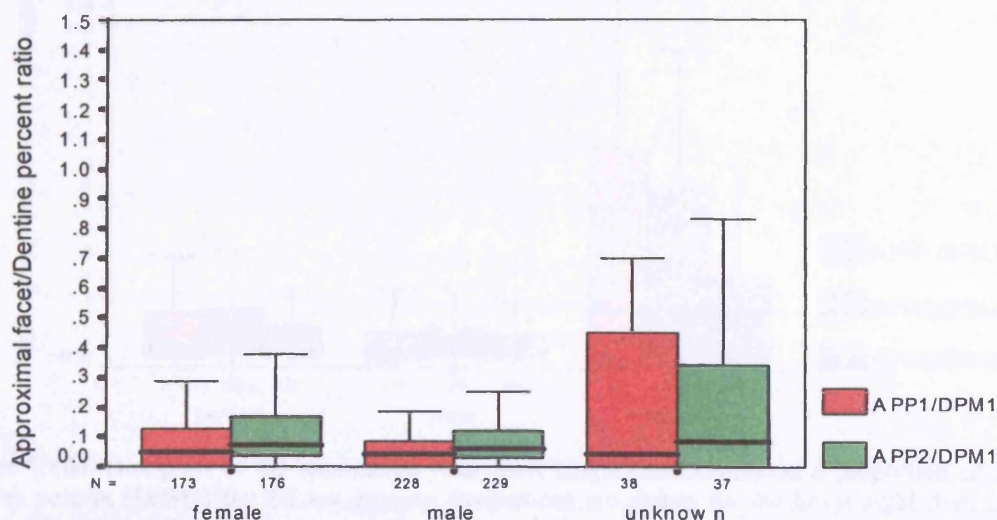


Figure 7.104: Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the sex groups. Proportions are shown for the lower left first and second premolars (P1 and P2).



### Approximal facet/Dentine percent ratio lower right molars

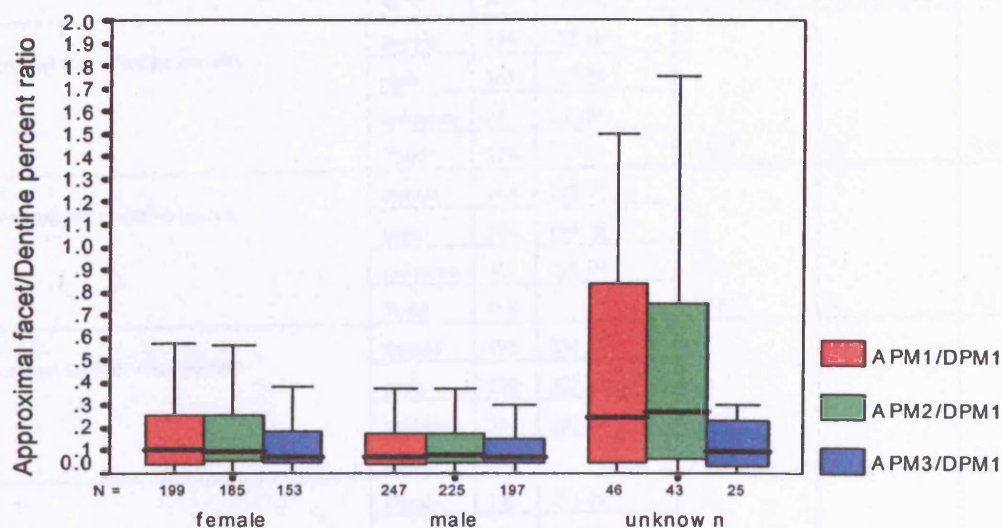


Figure 7.105: Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the sex groups. Proportions are shown for the lower right first, second and third molars (M1, M2 and M3).

### Approximal facet/Dentine percent ratio lower left molars

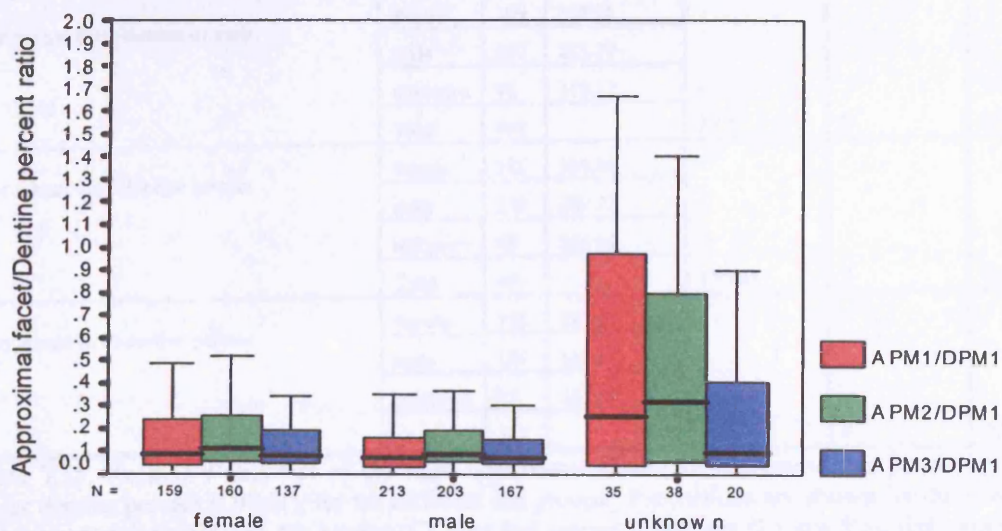


Figure 7.106: Box plots of the approximal wear facet length (AP) expressed a proportion of first molar dentine percent (DPM1) for the sex groups. Proportions are shown for the lower right first, second and third molars (M1, M2 and M3).

**Kruskal-Wallis test lower right**

	SEX	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/dentine percent I1	female	134	162.18	5.573	2	0.062
	male	165	155.89			
	unknown	24	202.98			
	Total	323				
Approximal facet/dentine percent I2	female	164	212.70	3.437	2	0.176
	male	210	194.78			
	unknown	34	224.99			
	Total	408				
Approximal facet/dentine percent C	female	190	234.37	1.614	2	0.446
	male	229	223.83			
	unknown	34	207.13			
	Total	453				
Approximal facet/dentine percent P1	female	186	231.28	1.361	2	0.506
	male	225	217.03			
	unknown	36	229.94			
	Total	447				
Approximal facet/dentine percent P2	female	184	234.17	4.233	2	0.120
	male	235	221.40			
	unknown	41	266.22			
	Total	460				
Approximal facet/dentine percent M1	female	199	255.68	17.87	2	0.000
	male	247	225.77			
	unknown	46	318.13			
	Total	492				
Approximal facet/dentine percent M2	female	185	234.46	13.081	2	0.001
	male	225	209.72			
	unknown	43	285.34			
	Total	453				
Approximal facet/dentine percent M3	female	153	187.60	0.020	2	0.990
	male	197	188.61			
	unknown	25	185.64			
	Total	375				

Table 7.25: Kruskal-Wallis test of the right approximal wear (AP), expressed as proportion of the first molar dentine percent (DPM1), for the different sex groups. Proportions are shown for the lower right first and second incisors (I1 and I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2 and M3).



**Kruskal-Wallis test lower left**

	SEX	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/dentine percent I1	female	131	159.40	4.646	2	0.098
	male	162	151.10			
	unknown	21	195.00			
	Total	314				
Approximal facet/dentine percent I2	female	148	187.63	4.104	2	0.088
	male	199	181.82			
	unknown	32	200.86			
	Total	379				
Approximal facet/dentine percent C	female	174	223.38	2.767	2	0.251
	male	222	205.35			
	unknown	32	229.72			
	Total	428				
Approximal facet/dentine percent P1	female	173	232.34	4.141	2	0.126
	male	228	208.33			
	unknown	38	233.83			
	Total	439				
Approximal facet/dentine percent P2	female	176	234.21	4.334	2	0.115
	male	229	209.36			
	unknown	37	236.19			
	Total	442				
Approximal facet/dentine percent M1	female	159	212.02	411.360	2	0.003
	male	213	189.26			
	unknown	35	257.27			
	Total	407				
Approximal facet/dentine percent M2	female	160	208.12	10.747	2	0.005
	male	203	186.20			
	unknown	38	250.09			
	Total	401				
Approximal facet/dentine percent M3	female	137	167.81	1.156	2	0.561
	male	167	157.13			
	unknown	20	171.00			
	Total	324				

Table 7.26: Kruskal-Wallis test of the left approximal wear (AP), expressed as proportion of the first molar dentine percent (DPM1), for the different sex groups. Proportions are shown for the lower right first and second incisors (I1 and I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2 and M3).

The Kruskal-Wallis tests (Tables 7.25 and 7.26) show that, for almost all teeth, the median ratios are not significant. M1 and M2 show significant differences, with higher ratios in the females, but these differences are very small.

### **Occlusal angle measurement of the male, female and unknown sex individuals**

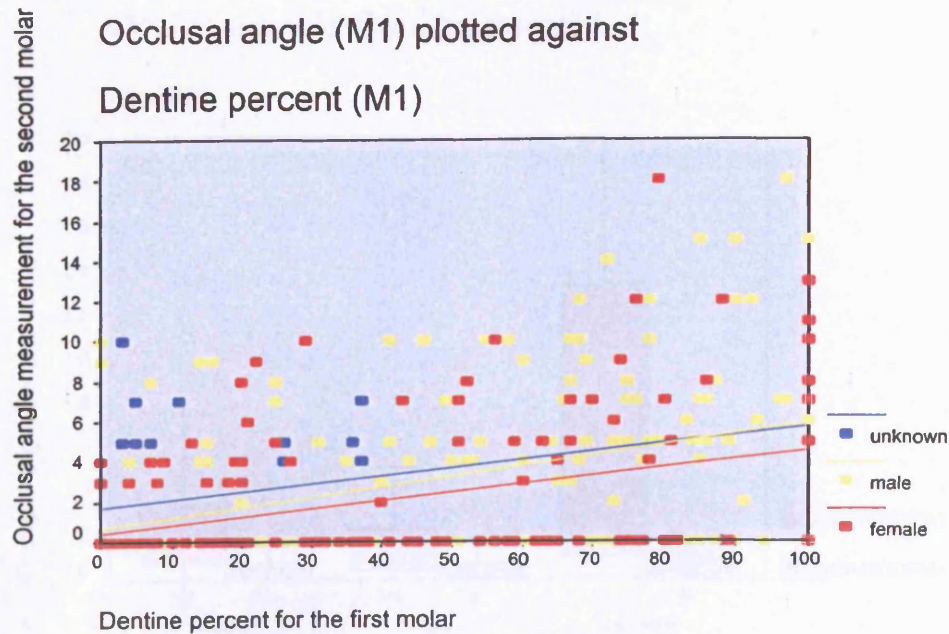


Figure 7:107: Scatter plot of the M1 occlusal angle plotted against M1 occlusal wear (dentine percent), for different sex groups.

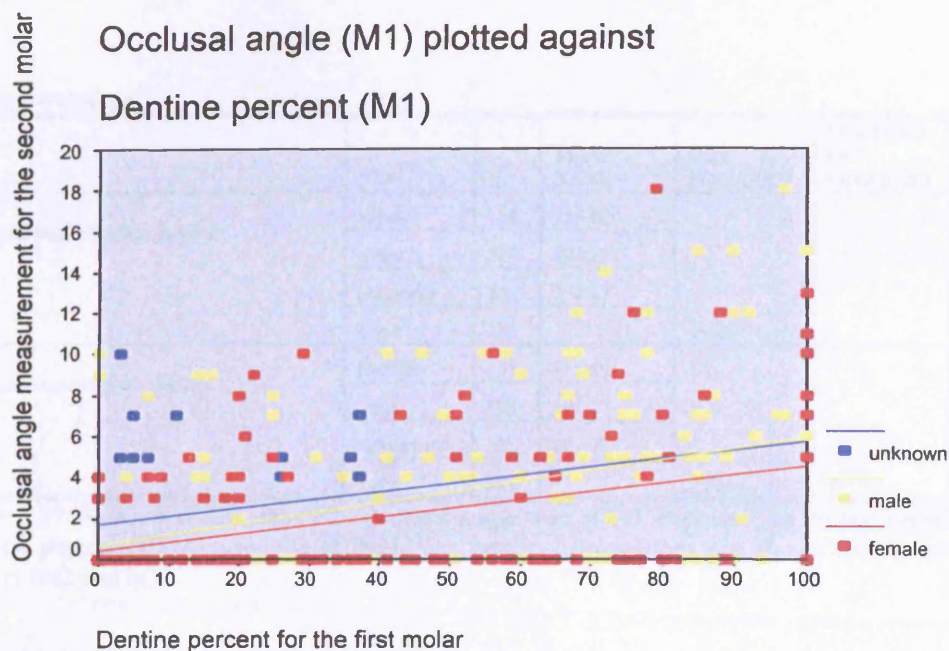


Figure 7:108: Scatter plot of the M2 occlusal angle plotted against M1 occlusal wear (dentine percent), for different sex groups.

Occlusal angle scatter plot Figures 7.107 and 7.108 shows extensive overlap between the males, females and unknown sexed individuals. The box plot (Figures 7.109) of the occlusal angle/dentine percent ratios also show only small differences between medians of the males and females. The interquartile range of females is slightly higher than the males and the range of the unknown sexed individuals is markedly higher than either the known sex groups.

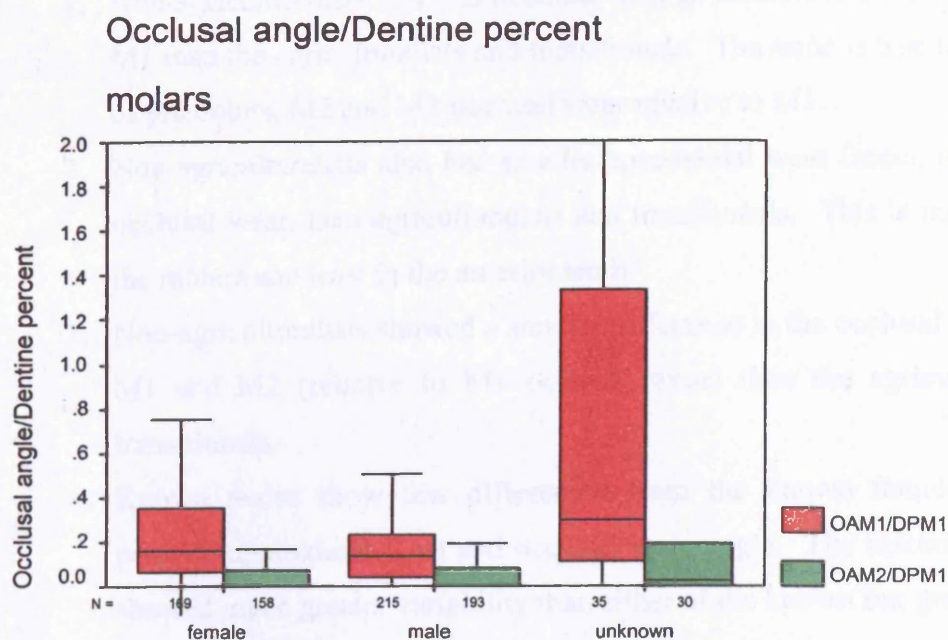


Figure 7.109: Box plots of the occlusal wear plane angle (OA), expressed as proportion of the first molar dentine percent (DPM1), for the sex groups. Proportions are shown for the first and second molars (M1 and M2).

#### Kruskal-Wallis test

	SEX	N	MEAN RANK	CHI SQUARED	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Occlusal angle/dentine percent M1	female	169	216.82	14.227	2	0.001
	male	215	194.18			
	unknown	35	274.27			
	Total	419				
Occlusal angle/dentine percent M2	female	158	177.69	7.931	2	0.019
	male	193	196.27			
	unknown	30	227.23			
	Total	381				

Table 7.27: Kruskal-Wallis test of the occlusal angle wear (OA), expressed as proportion of the first molar dentine percent (DPM1), for the different sex groups. Proportions are shown for the second and third molars (M2 and M3).

The Kruskal-Wallis tests (Table 7.27) suggest that there are differences between the sexes, but the unknown sexed group shows the largest difference of the known sex groups.

Overall, the known males show few differences from the known females in dentine percent, approximal facet and occlusal wear angle. The unknown sex group showed much greater variability than either of the known sex groups.

#### Summary:

1. Non-agriculturalists had less occlusal wear in incisors and canines relative to M1 than the agriculturalists and transitionals. The same is true to some extent of premolars, M2 and M3 occlusal wear relative to M1.
2. Non-agriculturalists also had smaller approximal wear facets, relative to M1 occlusal wear, than agriculturalists and transitionals. This is most marked in the molars and least in the anterior teeth.
3. Non-agriculturalists showed a smaller difference in the occlusal wear angle in M1 and M2 (relative to M1 occlusal wear) than the agriculturalists and transitionals.
4. Known males show few differences from the known females in dentine percent, approximal facet and occlusal wear angle. The unknown sex group showed much greater variability than either of the known sex groups.



## 7.2.B Coastal agriculturalists plotted against coastal non-agriculturalists

This section compares the coastal agricultural group (Florida Canaveral Peninsula) to the coastal non-agricultural group (Santa Barbara Channel Island).

### Dentine percent

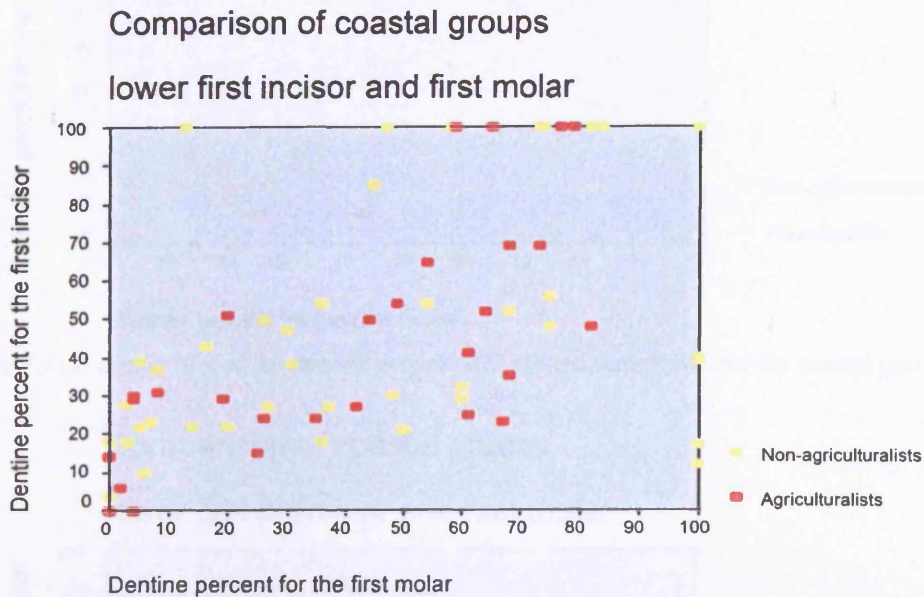


Figure 7.110: Scatter plot of the dentine percent of I1 plotted against M1 for the coastal groups.

The scatters of points show a general rise of I1 dentine percent with M1 dentine percent but the non-agriculturalists overlap extensively with the agriculturalists, and it is not possible to see any consistent differences between these two coastal groups. The same can be said for the rest of the dental arcade (Figures 7.110-7.116).

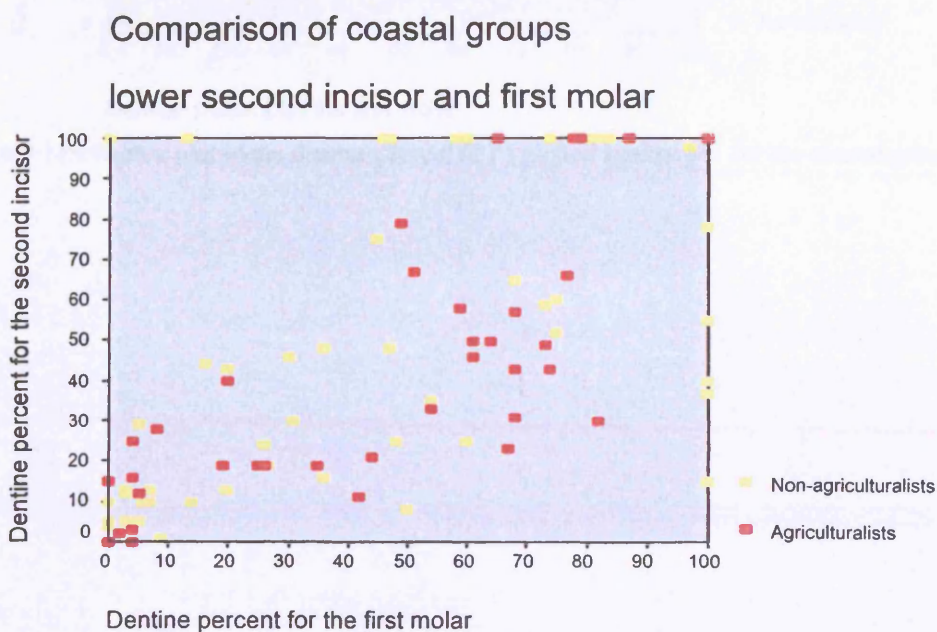


Figure 7.111: Scatter plot of the dentine percent of I2 plotted against M1 for the coastal groups.

## Comparison of coastal groups

## lower canine and first molar

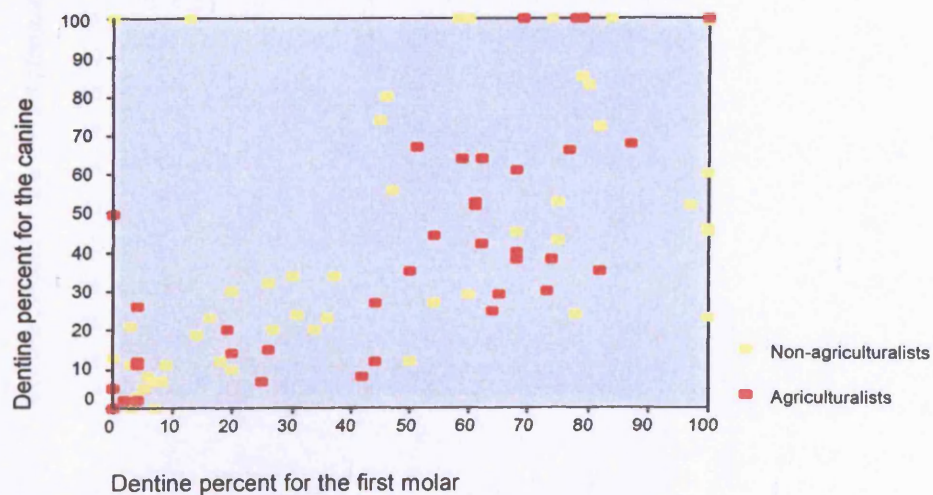


Figure 7.112: Scatter plot of the dentine percent of C plotted against M1 for the coastal groups.

## Comparison of coastal groups

## lower first premolar and first molar

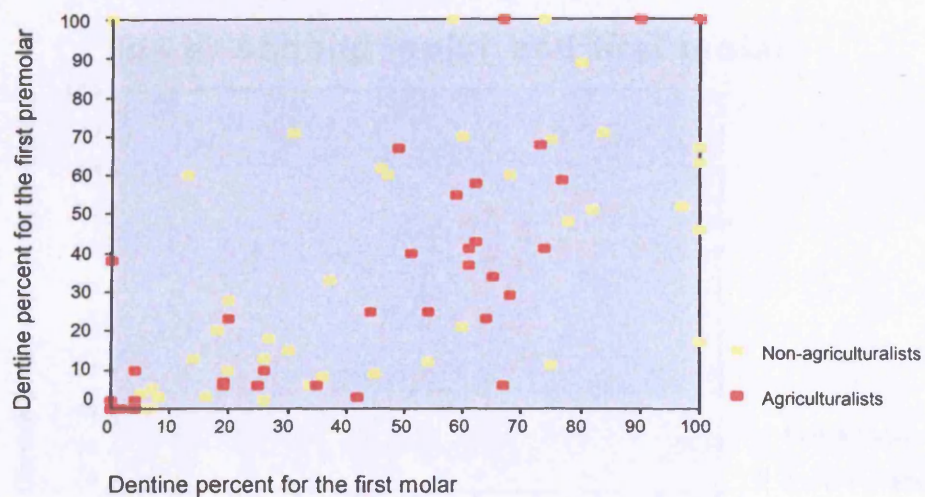


Figure 7.113: Scatter plot of the dentine percent of P1 plotted against M1 for the coastal groups.



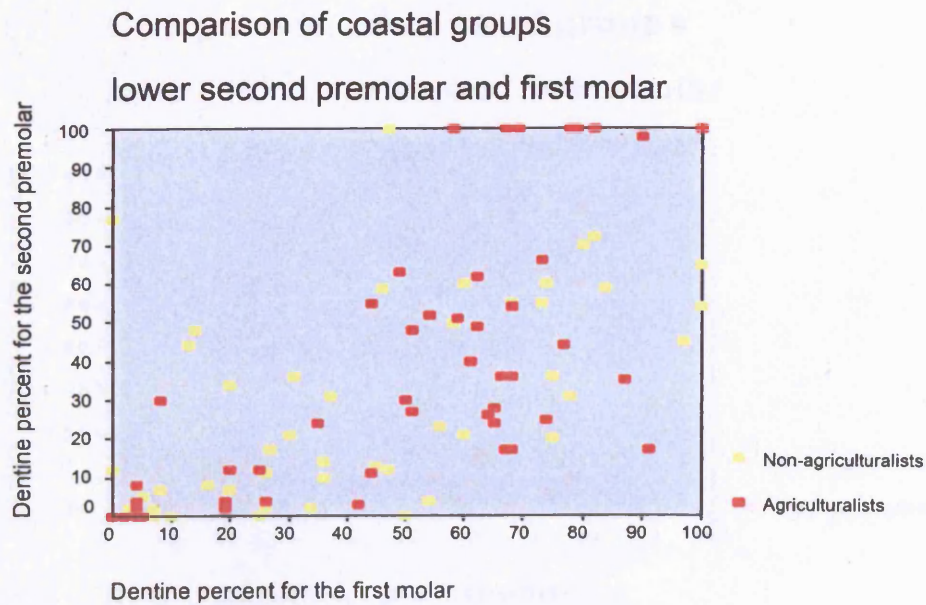


Figure 7.114: Scatter plot of the dentine percent of P2 plotted against M1 for the coastal groups.

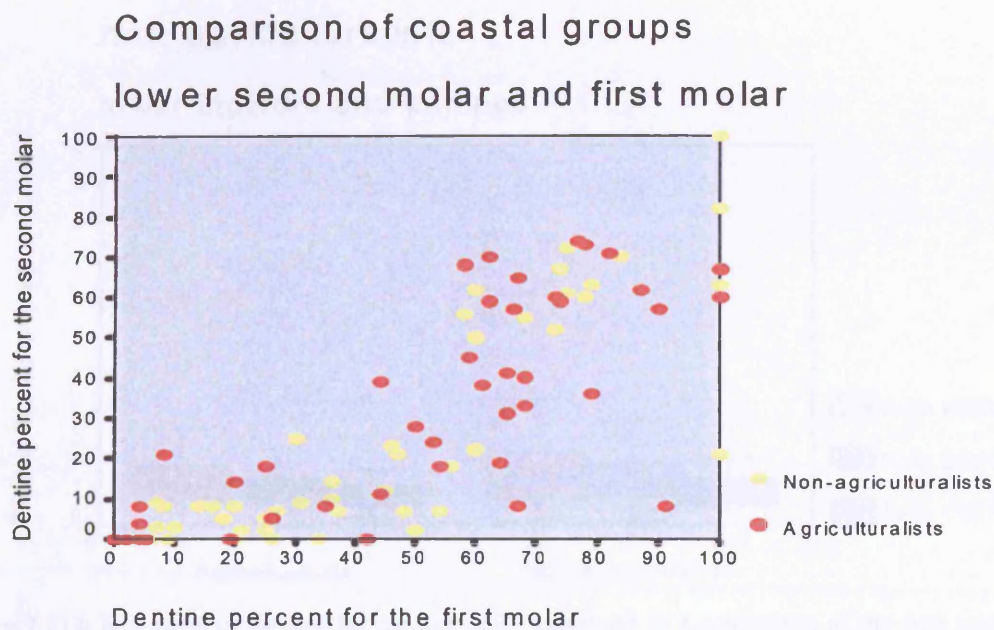


Figure 7.115: Scatter plot of the dentine percent of M2 plotted against M1 for the coastal groups.

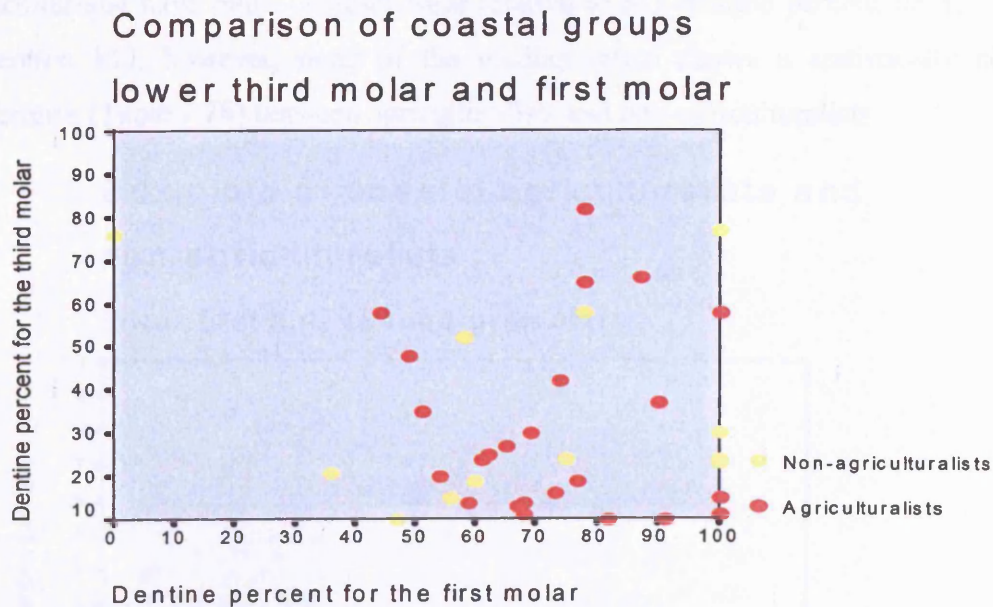


Figure 7.116 Scatter plot of the dentine percent of M3 plotted against M1 for the coastal groups.

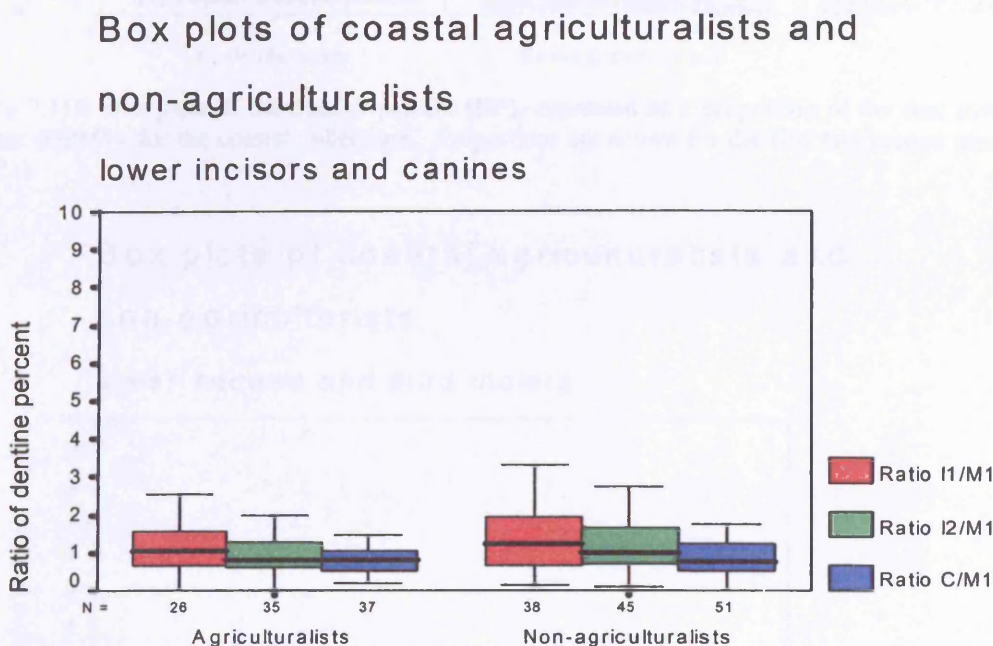


Figure 7.117: Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the coastal collections. Proportions are shown for the first incisor (I1), second incisor (I2), and canine (C).

Like the previous full collection dentine percent box plots (Figures 7.47-7.49) the interquartile range for the ratio decreases from I1 to I2 to C. The interquartile ranges for different tooth types overlap one another and between the two coastal assemblages. The non-agriculturalists have a larger interquartile range and overall range than the agriculturalists. The median ratio also has somewhat higher value in the coastal non-agriculturalists I1 and I2 than in the coastal agriculturalists. The C ratio however, shows the opposite. The implication of this is that the coastal non-agriculturalists have more occlusal wear in I1 and I2 for a given stage of M1 occlusal wear, but the coastal



agriculturalists have more occlusal wear relative to M1 dentine percent for C. With the exception M3, however, none of the median ratios shows a statistically significant difference (Table 7.28) between agriculturalists and non-agriculturalists.

### Box plots of coastal agriculturalists and non-agriculturalists

#### lower first and second premolars

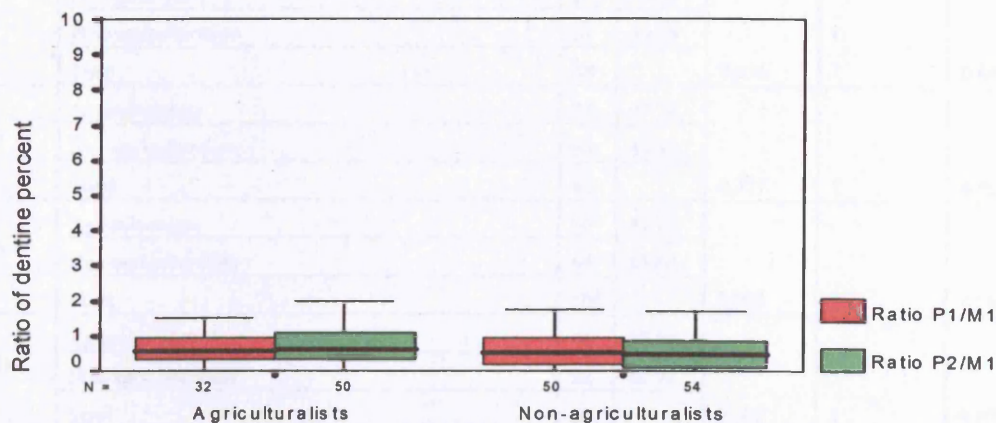


Figure 7.118: Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the coastal collections. Proportions are shown for the first and second premolars (P1 and P2).

### Box plots of coastal agriculturalists and non-agriculturalists

#### lower second and third molars

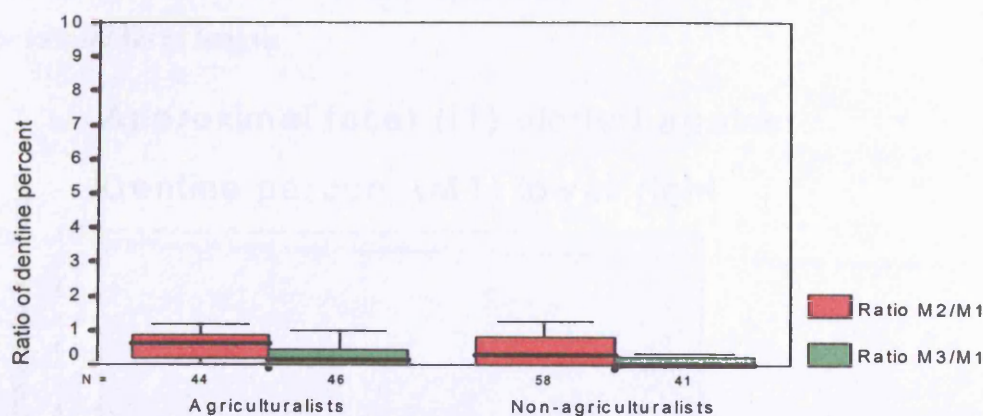


Figure 7.119: Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the coastal collections. Proportions are shown for the second and third molars (M2 and M3).

**Kruskal-Wallis**

COASTAL AGRICULTURALISTS AND COASTAL NON-AGRICULTURALISTS		N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Ratio I1/M1	Agriculturalists	26	30.46	0.525	1	0.469
	Non-agriculturalists	38	33.89			
	Total	64				
Ratio I2/M1	Agriculturalists	35	36.41	1.924	1	0.165
	Non-agriculturalists	45	43.68			
	Total	80				
Ratio C/M1	Agriculturalists	37	43.89	0.036	1	0.849
	Non-agriculturalists	51	44.94			
	Total	88				
Ratio P1/M1	Agriculturalists	32	43.38	0.327	1	0.568
	Non-agriculturalists	50	40.30			
	Total	82				
Ratio P2/M1	Agriculturalists	50	57.73	2.903	1	0.088
	Non-agriculturalists	54	47.66			
	Total	104				
Ratio M2/M1	Agriculturalists	44	57.56	3.280	1	0.070
	Non-agriculturalists	58	46.91			
	Total	102				
Ratio M3/M1	Agriculturalists	46	49.66	5.392	1	0.020
	Non-agriculturalists	41	37.65			
	Total	87				

Table 7.28 Kruskal-Wallis test of the dentine percent expressed as a proportion of the first molar dentine percent, for the different coastal groups. Proportions are shown for the first and second incisors (I1 and I2), canine (C), first and second premolars (P1 and P2), second and third molars (M2 and M3).

To summarise there were no clear differences in the pattern of occlusal wear between the coastal agriculturalists and non-agriculturalists.

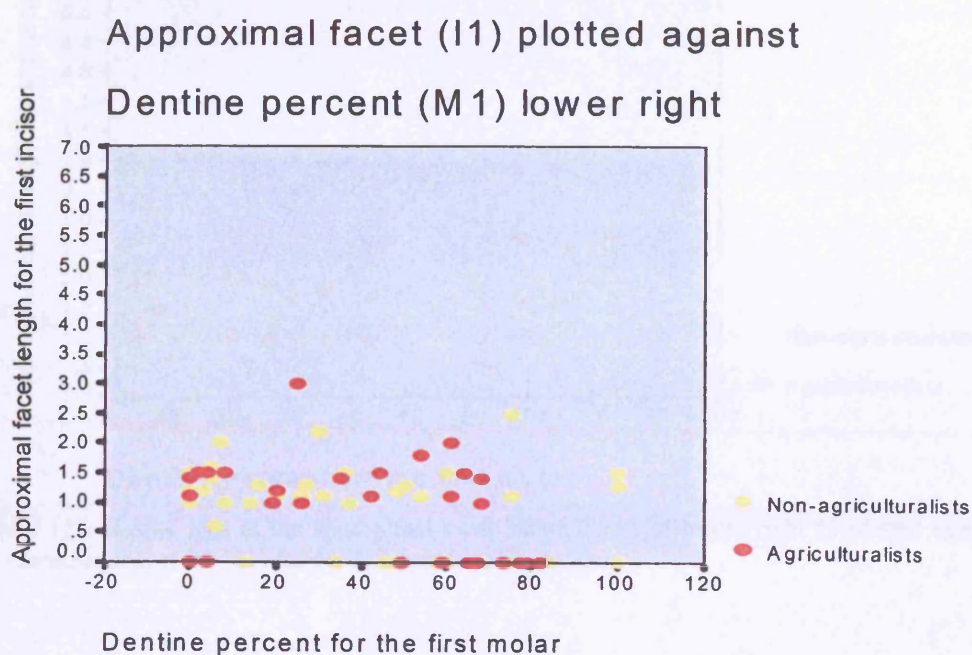
**Approximal facet length**

Figure 7.120: Scatter plot of the approximal facet length (mm) of lower right I1 plotted against occlusal wear (dentine percent for M1) for the different coastal groups.



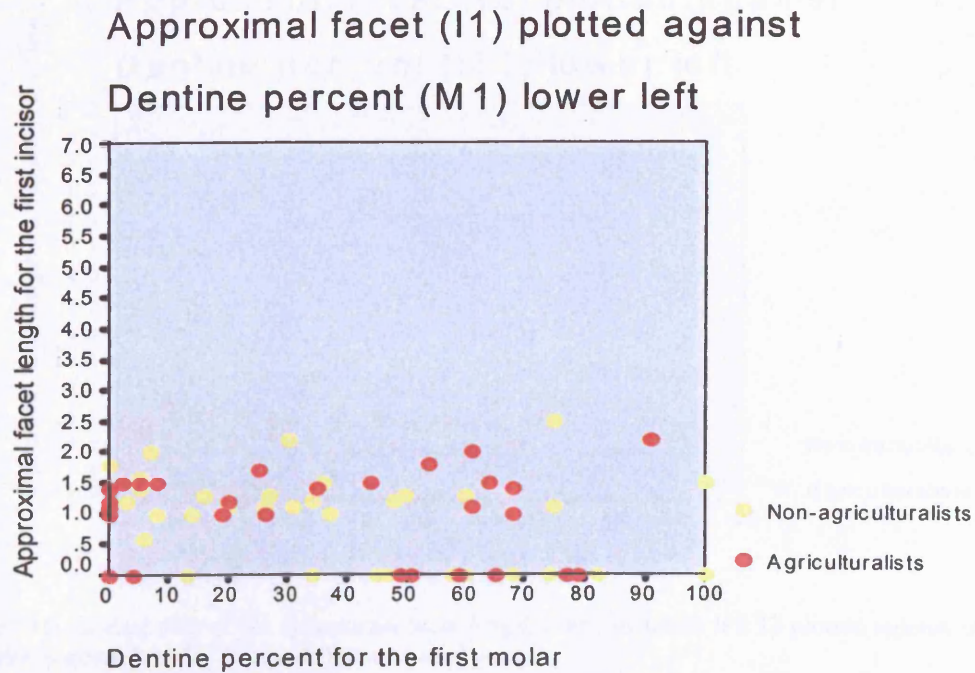


Figure 7.121: Scatter plot of the approximal facet length (mm) of lower left I1 plotted against occlusal wear (dentine percent for M1) for the different coastal groups.

The plots of approximal facet length versus M1 dentine percent for all teeth (Figures 7.121-7.135) show no consistent differences between coastal non-agriculturalists and agriculturalists. The scatters of points overlap one another to a large extent.

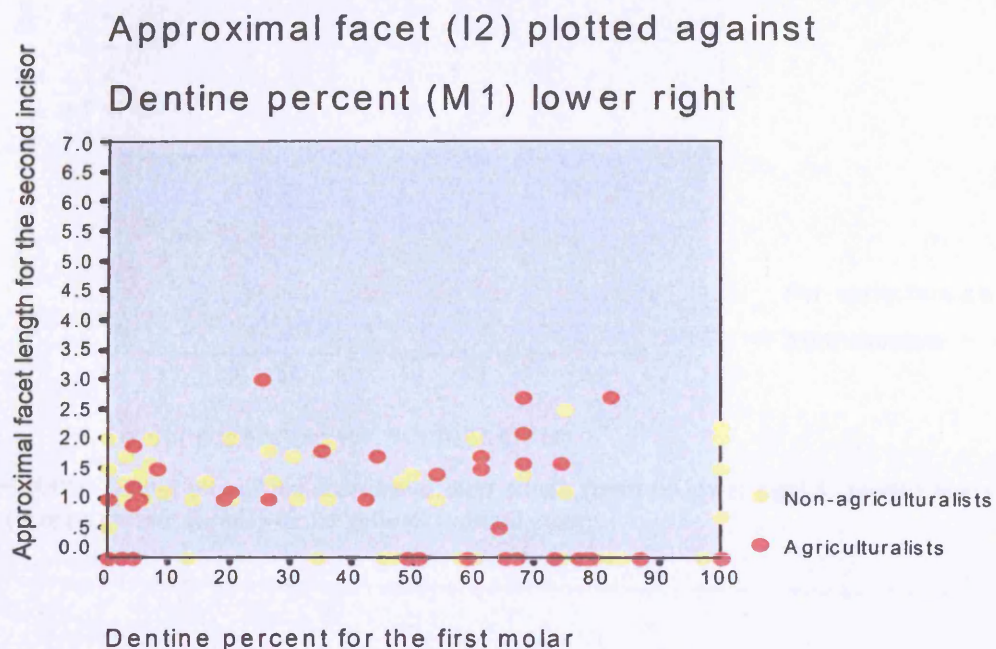


Figure 7.122: Scatter plot of the approximal facet length (mm) of lower right I2 plotted against occlusal wear (dentine percent for M1) for the different coastal groups.

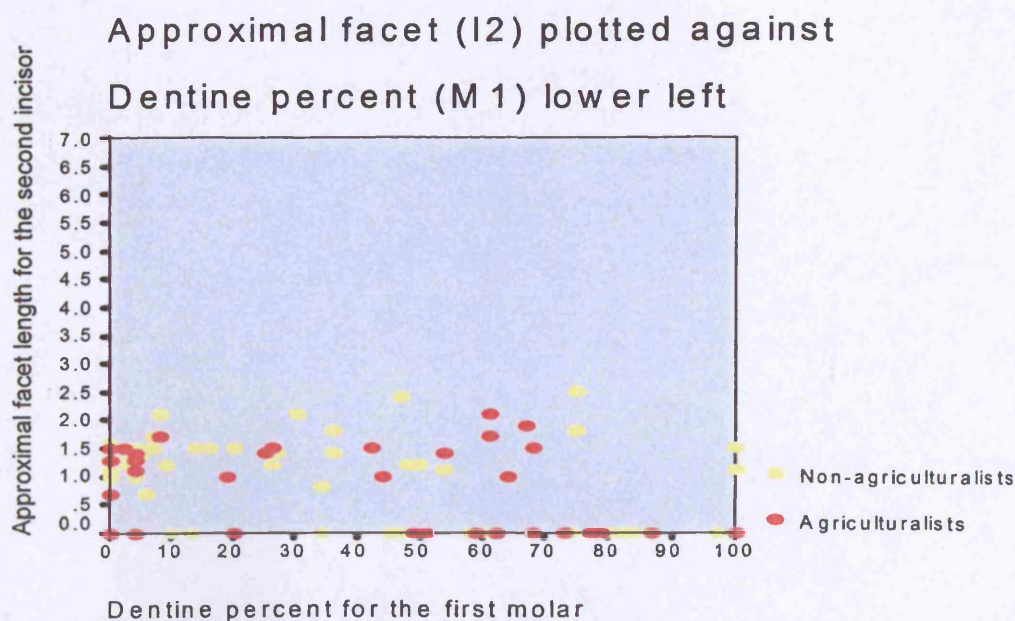


Figure 7.123: Scatter plot of the approximal facet length (mm) of lower left I2 plotted against occlusal wear (dentine percent for M1) for the different coastal groups.

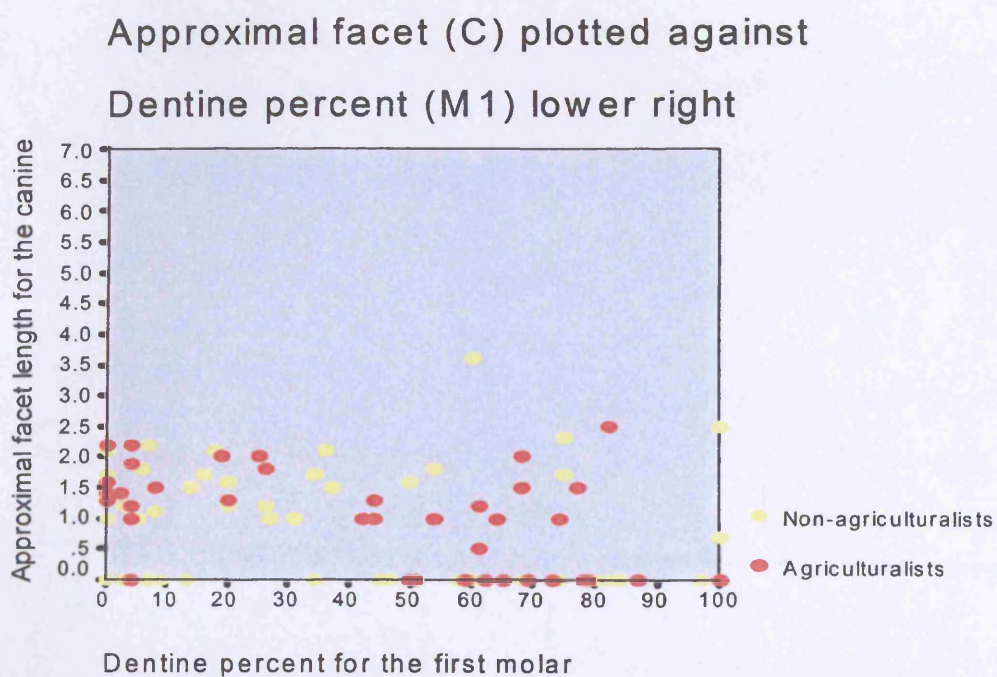


Figure 7.124: Scatter plot of the approximal facet length (mm) of lower right C plotted against occlusal wear (dentine percent for M1) for the different coastal groups.



### Approximal facet (C) plotted against Dentine percent (M1) lower left

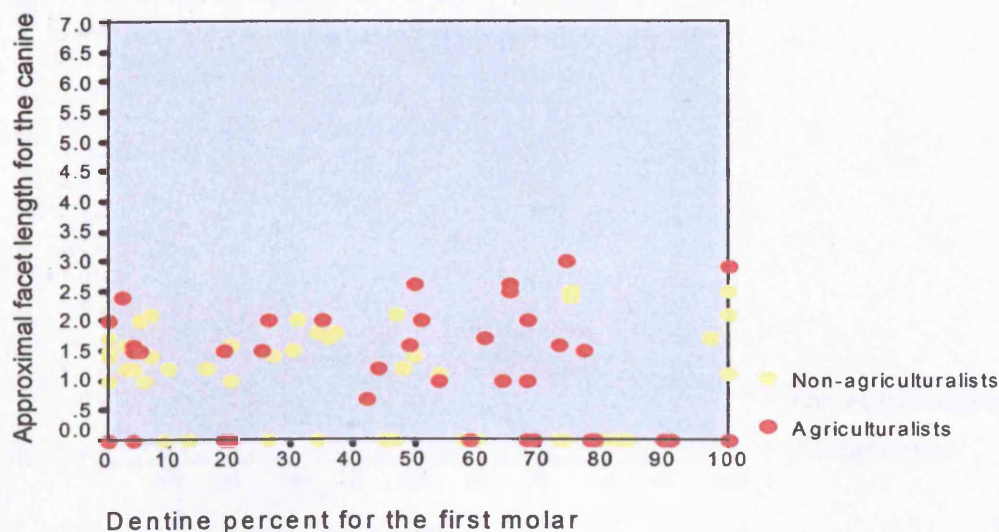


Figure 7.125: Scatter plot of the approximal facet length (mm) of lower left C plotted against occlusal wear (dentine percent for M1) for the different coastal groups.

### Approximal facet (P1) plotted against Dentine percent (M1) lower right

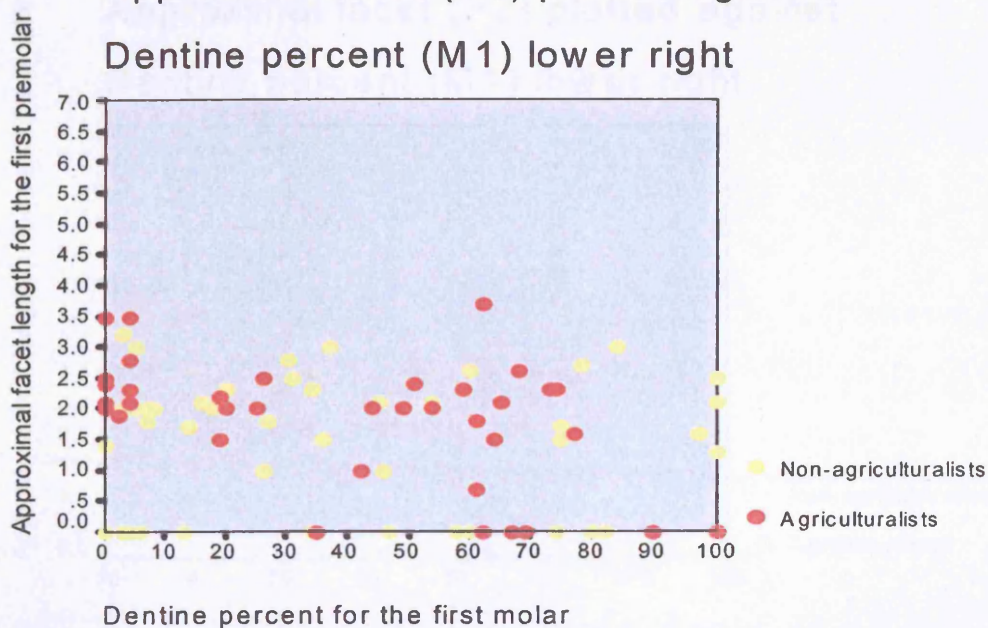


Figure 7.126: Scatter plot of the approximal facet length (mm) of lower right P1 plotted against occlusal wear (dentine percent for M1) for the different coastal groups.

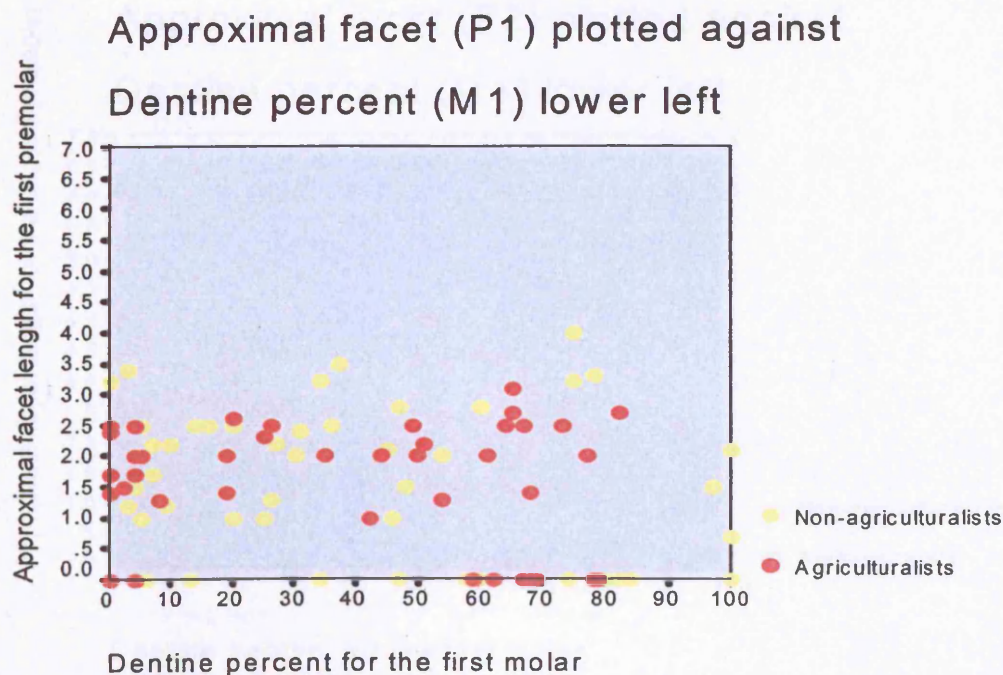


Figure 7.127: Scatter plot of the approximal facet length (mm) of lower left C plotted against occlusal wear (dentine percent for M1) for the different coastal groups.

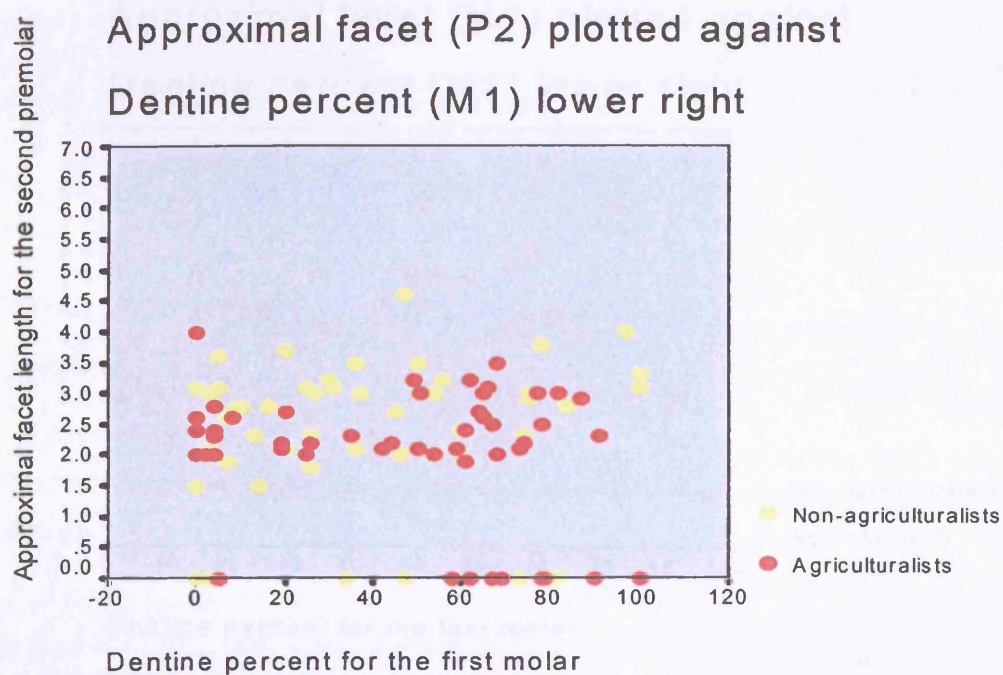


Figure 7.128 Scatter plot of the approximal facet length (mm) of lower right P2 plotted against occlusal wear (dentine percent for M1) for the different coastal groups.



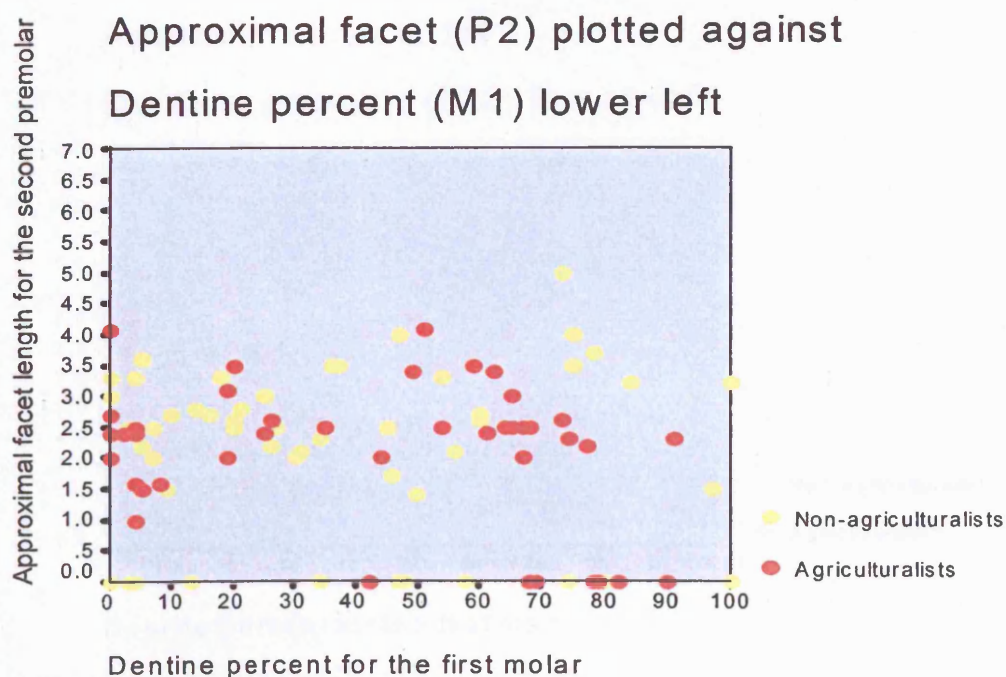


Figure 7.129: Scatter plot of the approximal facet length (mm) of lower left P2 plotted against occlusal wear (dentine percent for M1) for the different coastal groups.

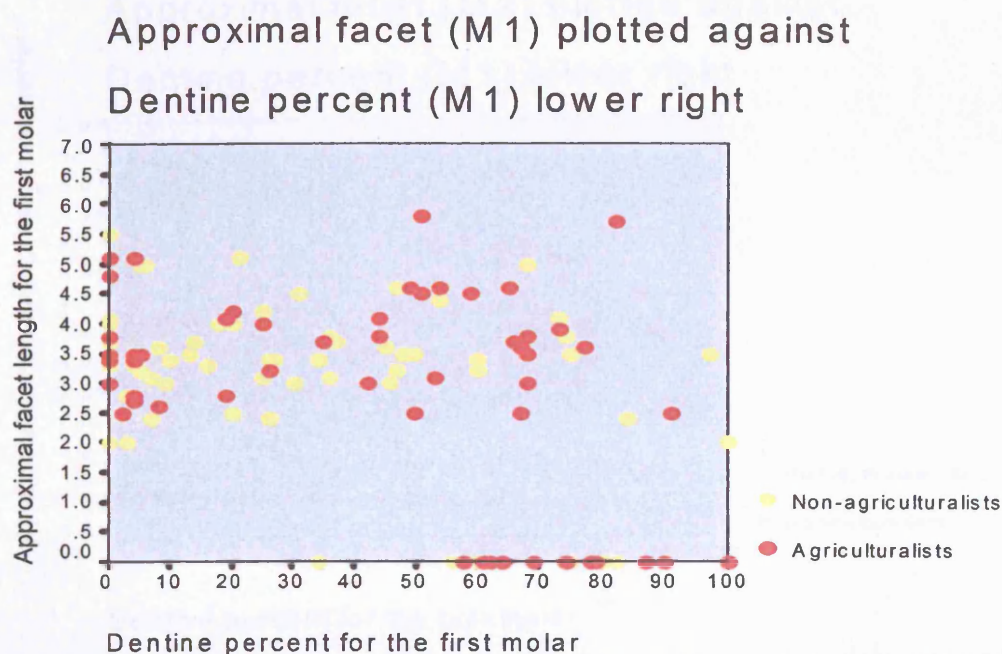


Figure 7.130: Scatter plot of the approximal facet length (mm) of lower right M1 plotted against occlusal wear (dentine percent for M1) for the different coastal groups.

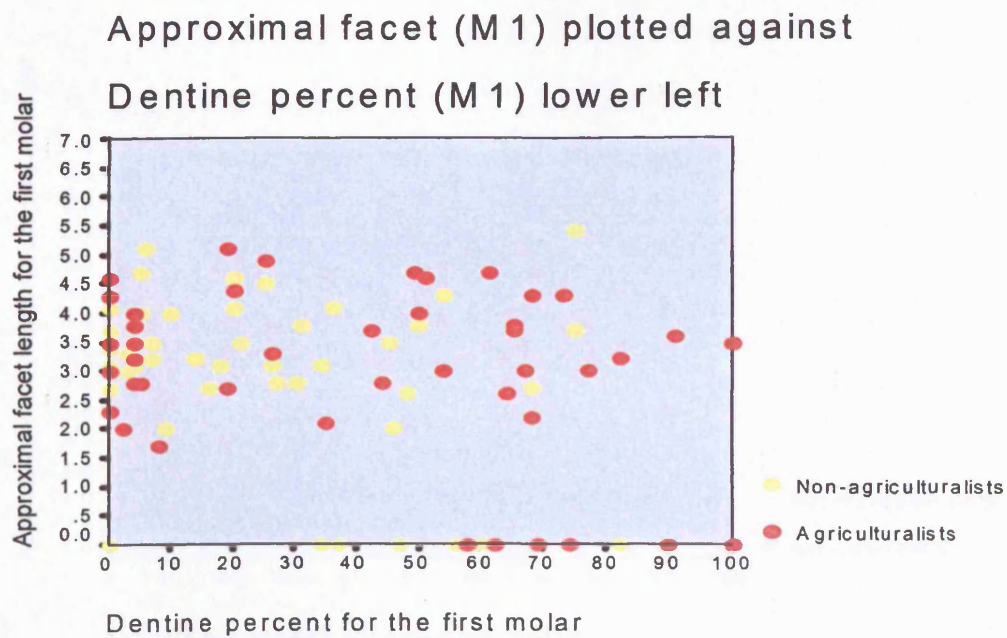


Figure 7.131: Scatter plot of the approximal facet length (mm) of lower left M1 plotted against occlusal wear (dentine percent for M1) for the different coastal groups.

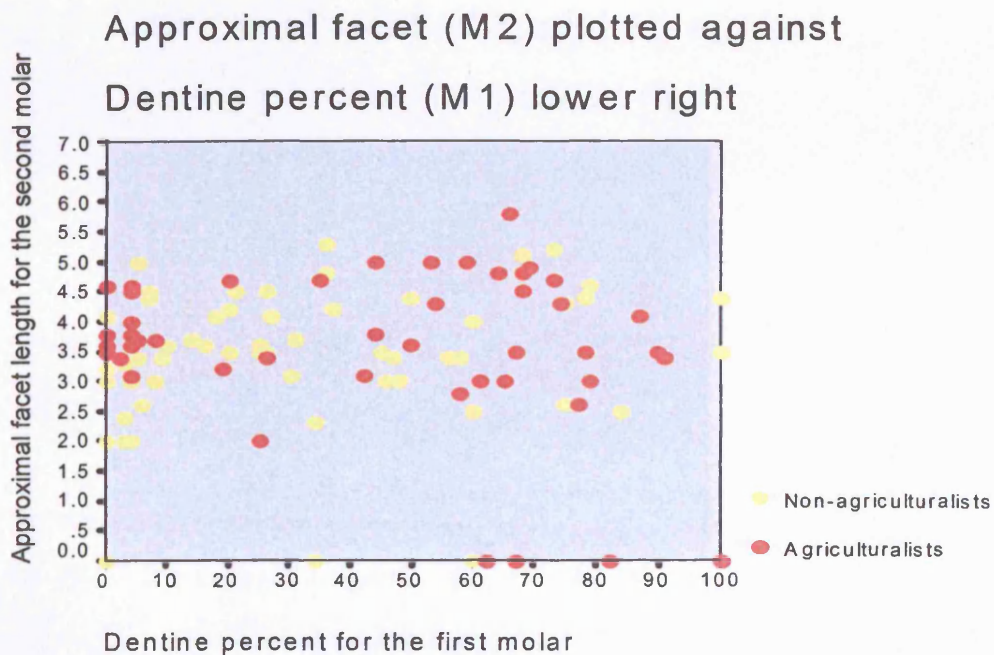


Figure 7.132: Scatter plot of the approximal facet length (mm) of lower right M2 plotted against occlusal wear (dentine percent for M1) for the different coastal groups.



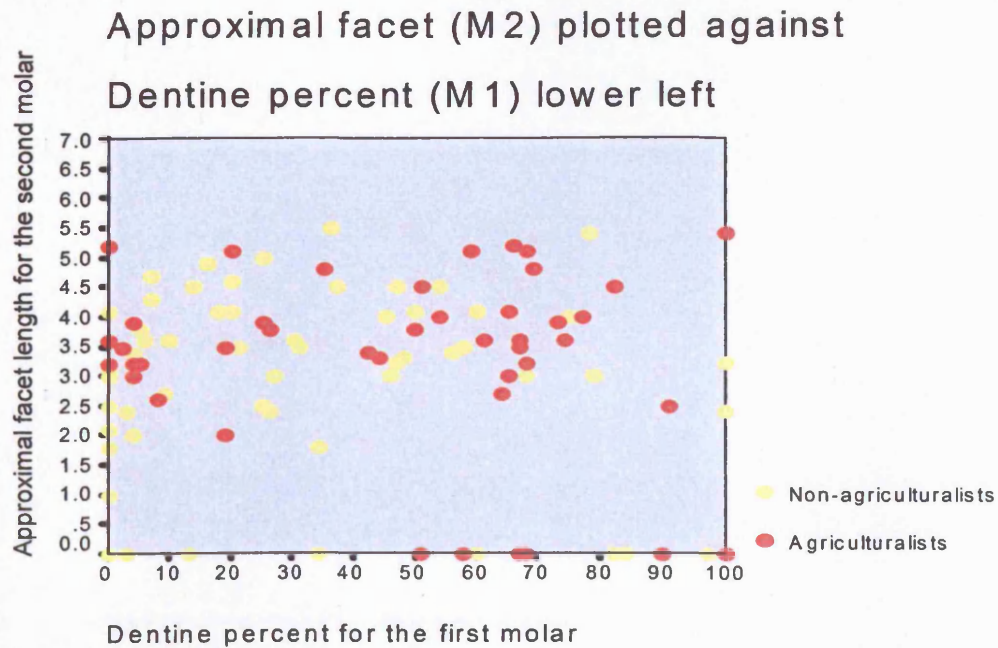


Figure 7.133: Scatter plot of the approximal facet length (mm) of lower left M2 plotted against occlusal wear (dentine percent for M1) for the different coastal groups.

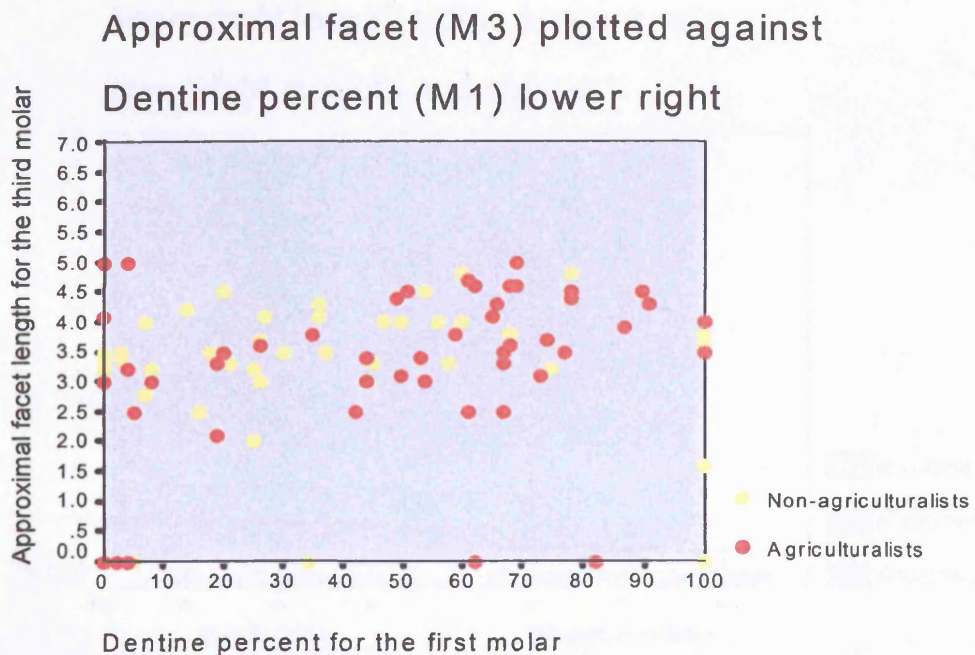


Figure 7.134: Scatter plot of the approximal facet length (mm) of lower right M3 plotted against occlusal wear (dentine percent for M1) for the different coastal groups.

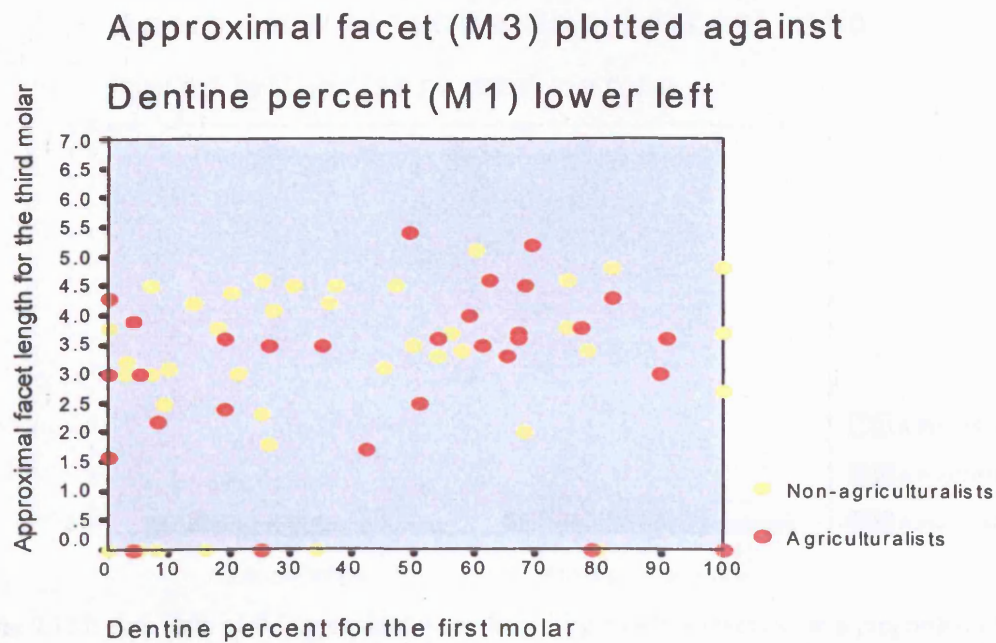


Figure 7.135: Scatter plot of the approximal facet length (mm) of lower left M3 plotted against occlusal wear (dentine percent for M1) for the different coastal groups.

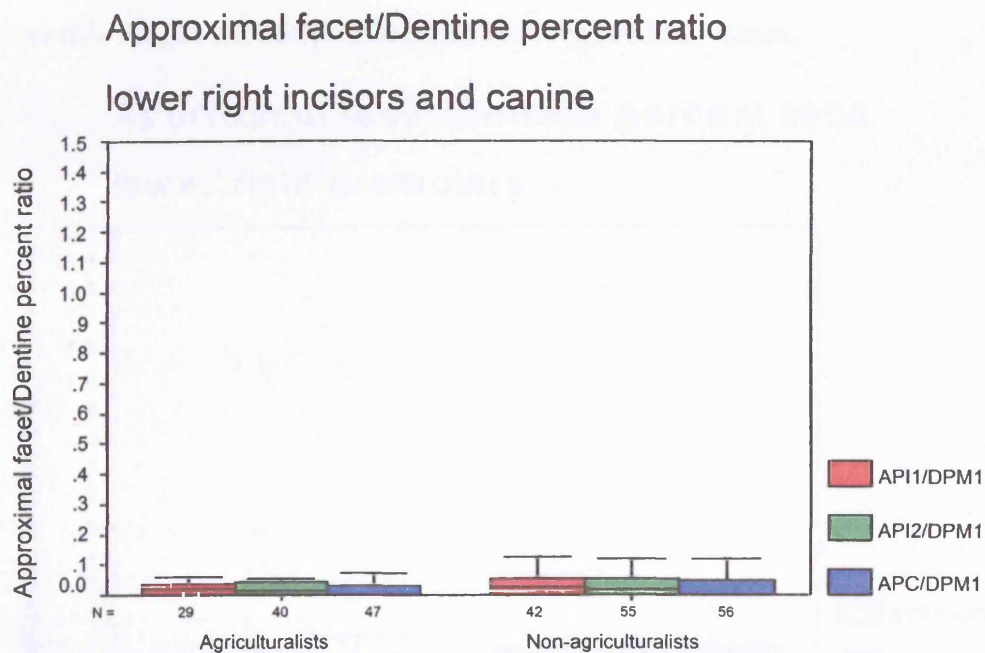


Figure 7.136: Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the coastal collections. Proportions are shown for the lower right first incisor (I1), second incisor (I2), and canine (C).

### Approximal facet/Dentine percent ratio lower left incisors and canine

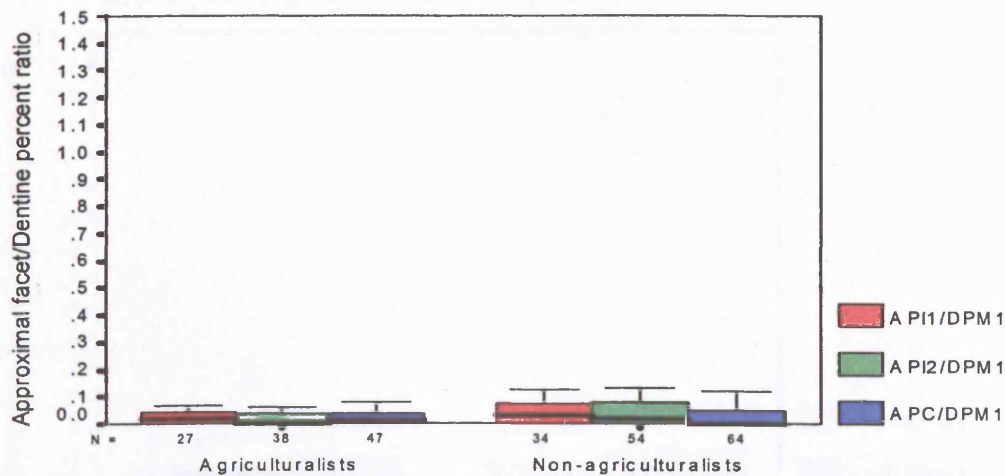


Figure 7.137: Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the coastal collections. Proportions are shown for the lower left first incisor (I1), second incisor (I2), and canine (C).

For approximal facet ratios in I1, I2 and C (Figures 7.136 and 7.137) there is even less variation than in the full collection (Figures 7.66 and 7.67) and extensive overlap of interquartile ranges with few differences between median values.

### Approximal facet/Dentine percent ratio lower right premolars

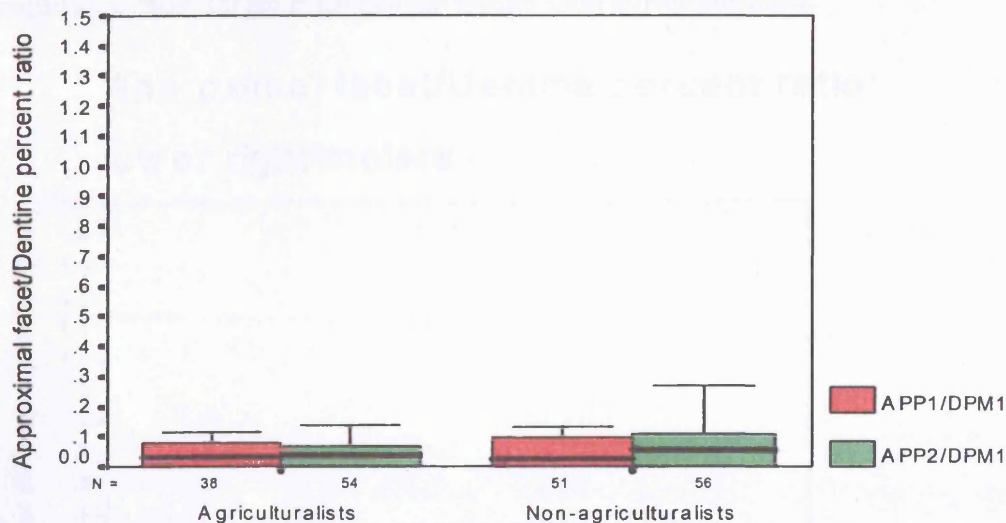


Figure 7.138: Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the coastal collections. Proportions are shown for the lower right first, and second premolars (P1 and P2).



## Approximal facet/Dentine percent ratio

### lower left premolars

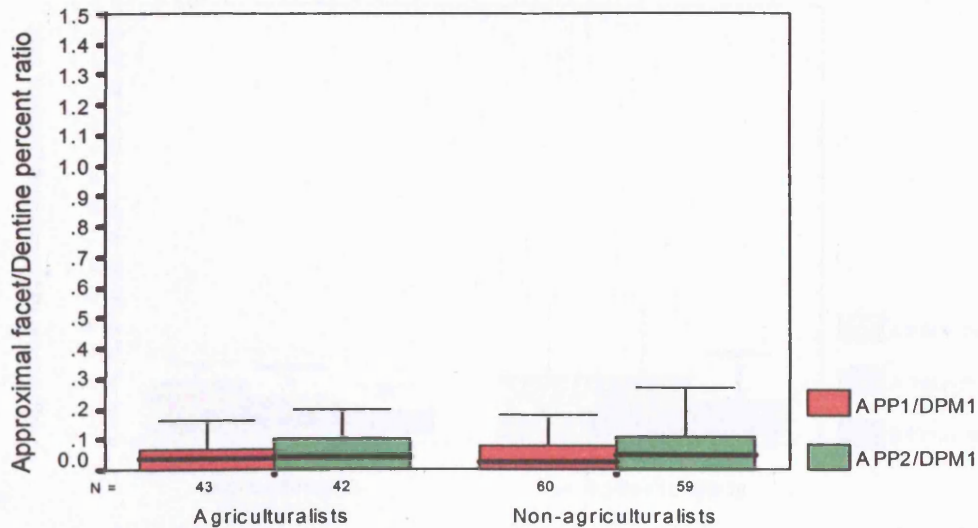


Figure 7.139: Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the full collection. Proportions are shown for the lower left first and second premolars (P1 and P2).

The box and whisker plots of the premolars (Figure 7.138 and 7.139) show a little more variation between the coastal behavioural groups but the median differences are small. For the molars (Figure 7.140 and 7.141) there is the expected approximal facet decrease from M1 to M2 to M3. As with the full collection (Figures 7.70 and 7.71), coastal non-agriculturalist show larger interquartile ranges than agriculturalists.

## Approximal facet/Dentine percent ratio

### lower right molars

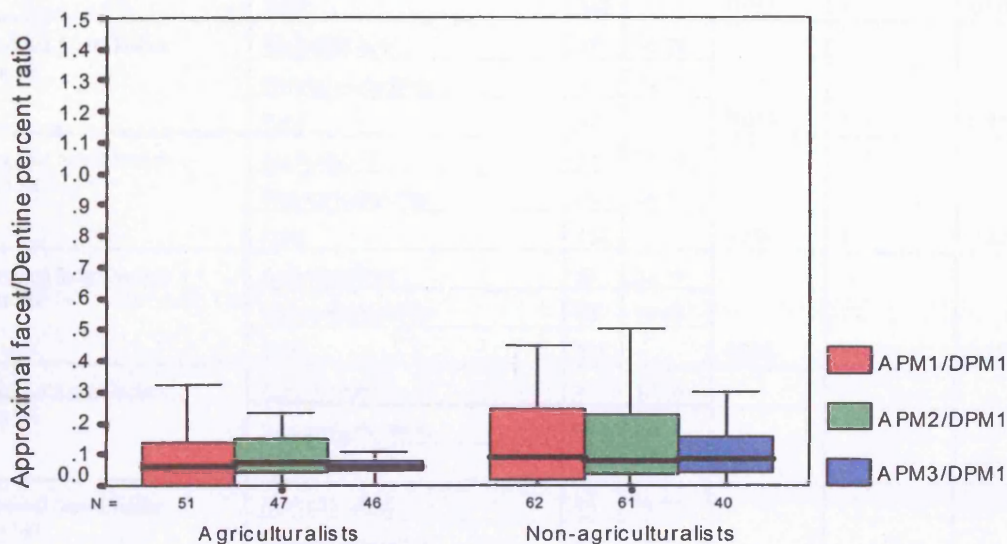


Figure 7.140: Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the coastal collections. Proportions are shown for the lower right first, second and third molars (M1, M2 and M3).



## Approximal facet/Dentine percent ratio

## lower left molars

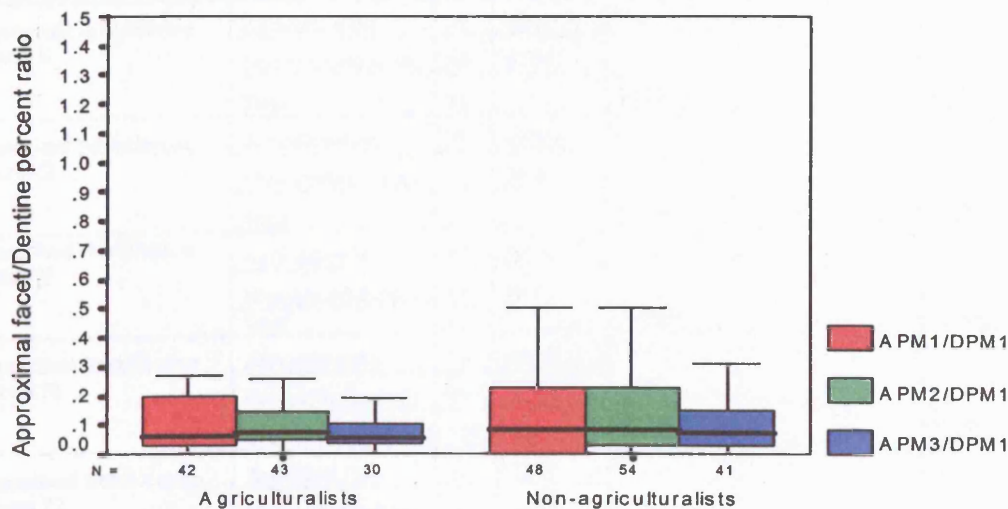


Figure 7.141: Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the coastal collections. Proportions are shown for the lower left first, second and third molars (M1, M2 and M3).

## Kruskal-Wallis test lower right

COASTAL AGRICULTURALISTS AND COASTAL NON-AGRICULTURALISTS		N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/Dentine percent I1	Agriculturalists	29	34.19	0.405	1	0.525
	Non-agriculturalists	42	37.25			
	Total	71				
Approximal facet/Dentine percent I2	Agriculturalists	40	46.96	0.109	1	0.742
	Non-agriculturalists	55	48.75			
	Total	95				
Approximal facet/Dentine percent C	Agriculturalists	47	52.34	0.013	1	0.908
	Non-agriculturalists	56	51.71			
	Total	103				
Approximal facet/Dentine percent P1	Agriculturalists	38	45.58	0.035	1	0.852
	Non-agriculturalists	51	44.57			
	Total	89				
Approximal facet/Dentine percent P2	Agriculturalists	54	51.64	1.590	1	0.207
	Non-agriculturalists	56	59.22			
	Total	110				
Approximal facet/Dentine percent M1	Agriculturalists	51	53.75	0.928	1	0.336
	Non-agriculturalists	62	59.67			
	Total	113				
Approximal facet/Dentine percent M2	Agriculturalists	47	53.36	0.111	1	0.739
	Non-agriculturalists	61	55.38			
	Total	108				
Approximal facet/Dentine percent M3	Agriculturalists	46	39.04	3.159	1	0.076
	Non-agriculturalists	40	48.63			
	Total	86				

Table 7.29: Kruskal-Wallis of the lower right approximal facet length (mm)/dentine percent for the first (I1) and second incisor (I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2, M3) ratios.

**Kruskal-Wallis lower left**

COASTAL AGRICULTURALISTS AND COASTAL NON-AGRICULTURALISTS		N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/Dentine percent I1	Agriculturalists	27	28.41	1.084	1	0.298
	Non-agriculturalists	34	33.06			
	Total	61				
Approximal facet/Dentine percent I2	Agriculturalists	38	43.05	1.254	1	0.264
	Non-agriculturalists	54	48.93			
	Total	92				
Approximal facet/Dentine percent C	Agriculturalists	47	56.86	0.069	1	0.793
	Non-agriculturalists	64	55.37			
	Total	111				
Approximal facet/Dentine percent P1	Agriculturalists	43	53.08	0.104	1	0.747
	Non-agriculturalists	60	51.23			
	Total	103				
Approximal facet/Dentine percent P2	Agriculturalists	42	51.55	0.026	1	0.872
	Non-agriculturalists	59	50.61			
	Total	101				
Approximal facet/Dentine percent M1	Agriculturalists	42	44.50	0.118	1	0.731
	Non-agriculturalists	48	46.38			
	Total	90				
Approximal facet/Dentine percent M2	Agriculturalists	43	46.65	0.543	1	0.461
	Non-agriculturalists	54	50.87			
	Total	97				
Approximal facet/Dentine percent M3	Agriculturalists	30	33.05	1.074	1	0.300
	Non-agriculturalists	41	38.16			
	Total	71				

Table 7.30: Kruskal-Wallis of the lower left approximal facet length (mm)/dentine percent for the first (I1) and second incisor (I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2, M3) ratios.

None of the differences between coastal agriculturalists and non-agriculturalists in approximal facet ratios reaches statistical differences.

To summarise, apart from a slightly higher variability of approximal facet length (relative to M1 dentine percent) in the non-agriculturalists, there are no clear differences between the coastal behavioural groups.

### Occlusal angle measurement

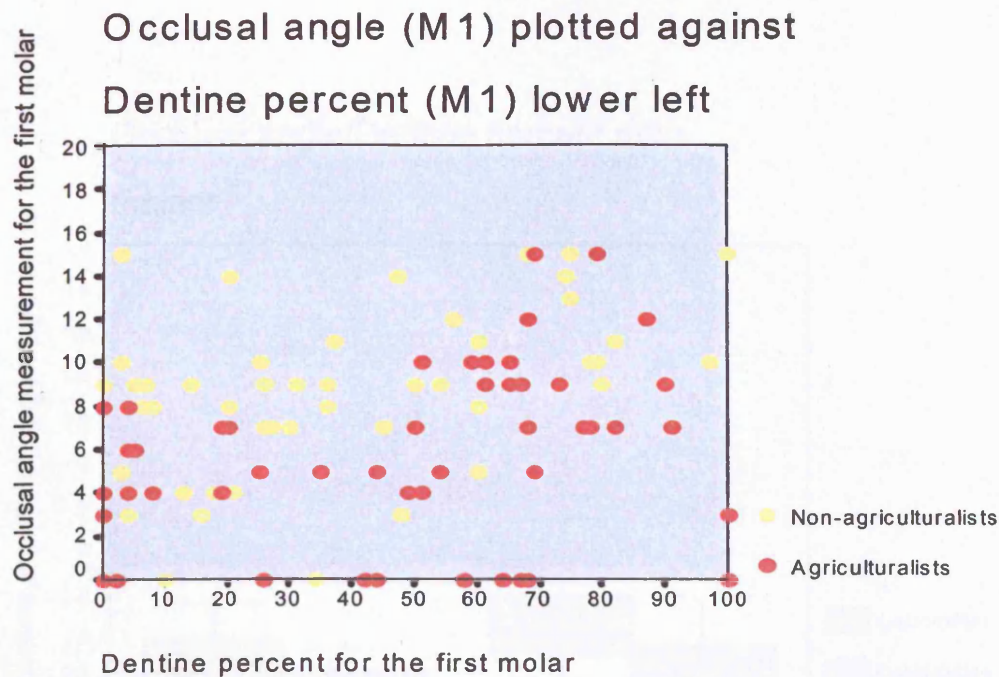


Figure 7.142: Scatter plot of the M1 occlusal angle plotted against M1 occlusal wear (dentine percent), for different coastal groups.

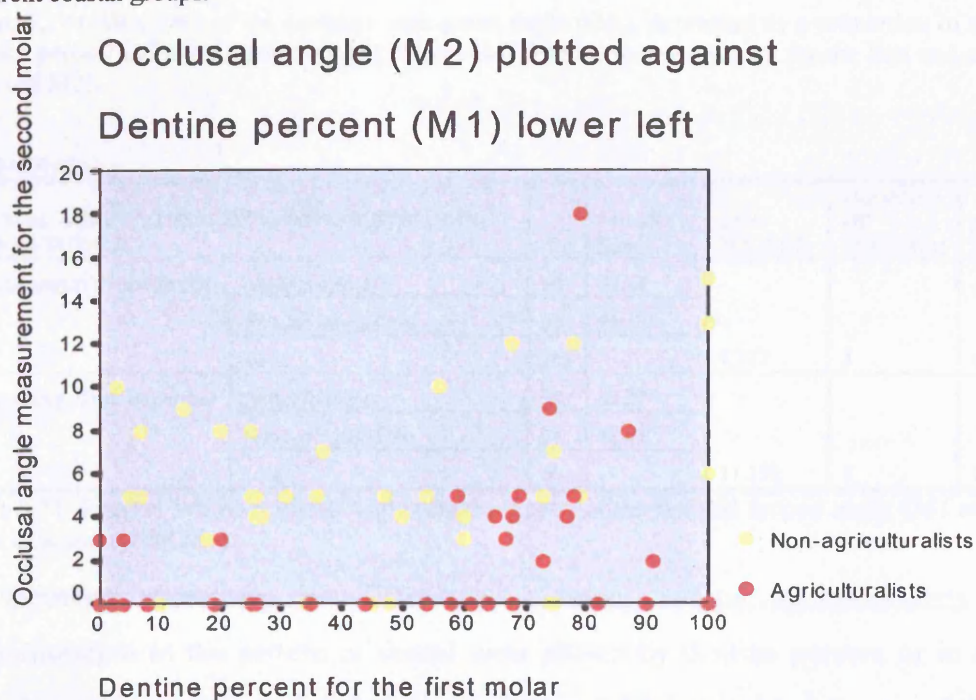


Figure 7.143: Scatter plot of the M1 occlusal angle plotted against M2 occlusal wear (dentine percent), for different coastal groups.

There is considerable overlap between the scatters of points (Figure 7.142 and 7.143), but in general the non-agriculturalists show larger angles for occlusal wear facets, for any given M1 occlusal wear stage. The box plot molar ratios (Figure 7.144) between occlusal angle/dentine percent and the differences in medians between coastal non-agriculturalists and coastal agriculturalists are highly significant (Table 7.31)



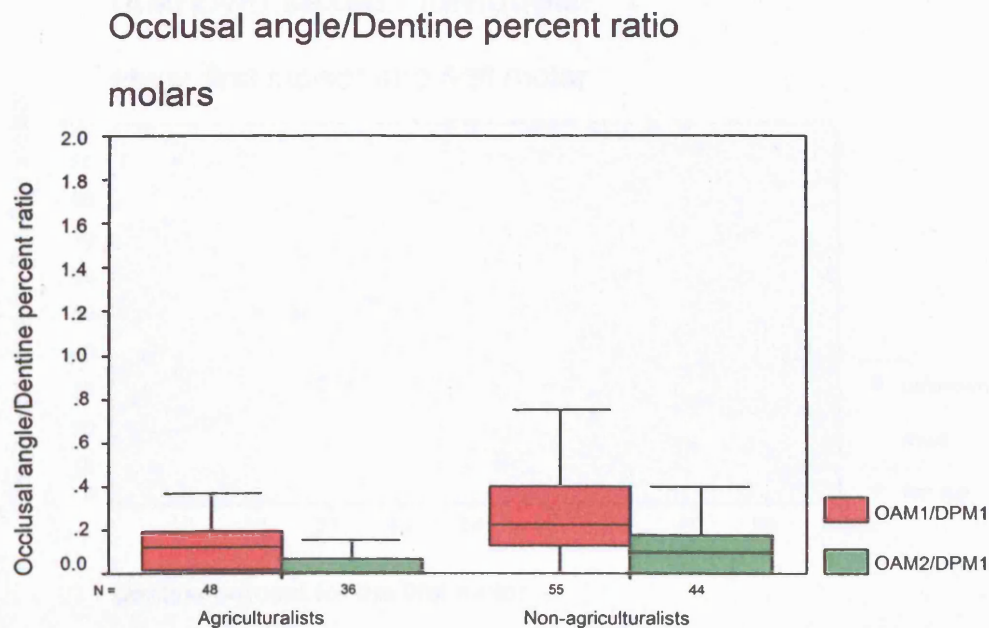


Figure 7.144: Box plots of the occlusal wear plane angle (OA), expressed as a proportion of the first molar dentine percent (DPM1), for the coastal collections. Proportions are shown for the first and second molars (M1 and M2).

#### Kruskal-Wallis

COASTAL AGRICULTURALISTS AND COASTAL NON-AGRICULTURALISTS		N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Occlusal angle/Dentine percent M1	Agriculturalists	48	41.48	1.217	1	0.001
	Non-agriculturalists	55	61.18			
	Total	103				
Occlusal angle/Dentine percent M2	Agriculturalists	36	31.32	11.150	1	0.001
	Non-agriculturalists	44	48.01			
	Total	80				

Table 7.31: Kruskal-Wallis occlusal angle (degrees) ratio of the first and second molar (M1 and M2) ratios (over dentine percent M1).

In summary, there are no differences between coastal agriculturalists and non-agriculturalists in the pattern of dental wear shown by dentine percent or in approximal facet length as a proportion to M1 occlusal wear. Molar occlusal wear angles, however, are greater for each stage of M1 occlusal wear in the non-agriculturalists.

#### Dentine percent comparison of the male, female and the unknown sex for the coastal behavioural groups



## Dentine percent of the males, females and unknown sexed individuals

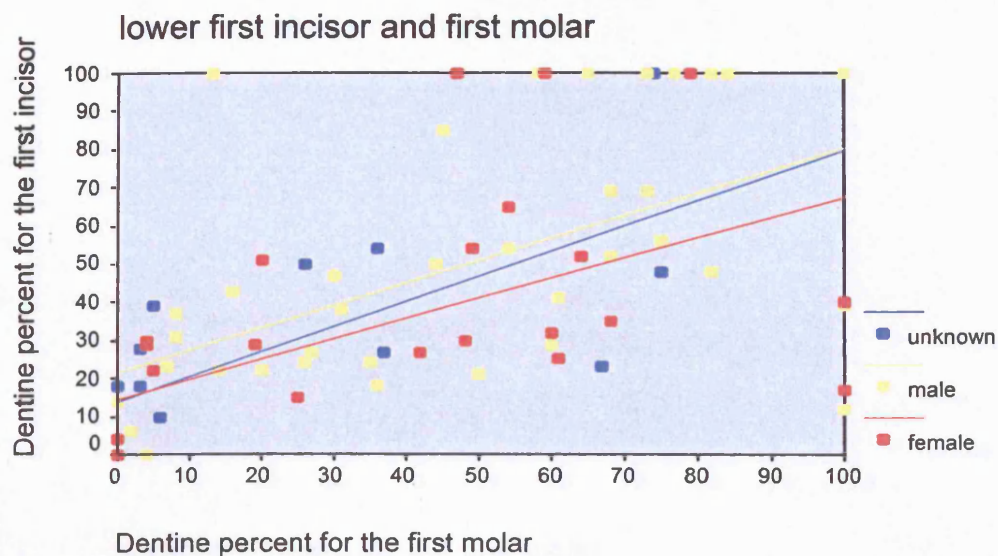


Figure 7.145: Scatter plot of the dentine percent of I1 plotted against M1 from the different sex groups.

Similar to the scatter plot of the full collection sex differences (Figures 7.75-81), the coastal sex groups (Figures 7.145-7.151) show that the scatters of points for the unknown sex, male and female groups overlap extensively for the full dental arcade.

## Dentine percent of the males, females and unknown sexed individuals

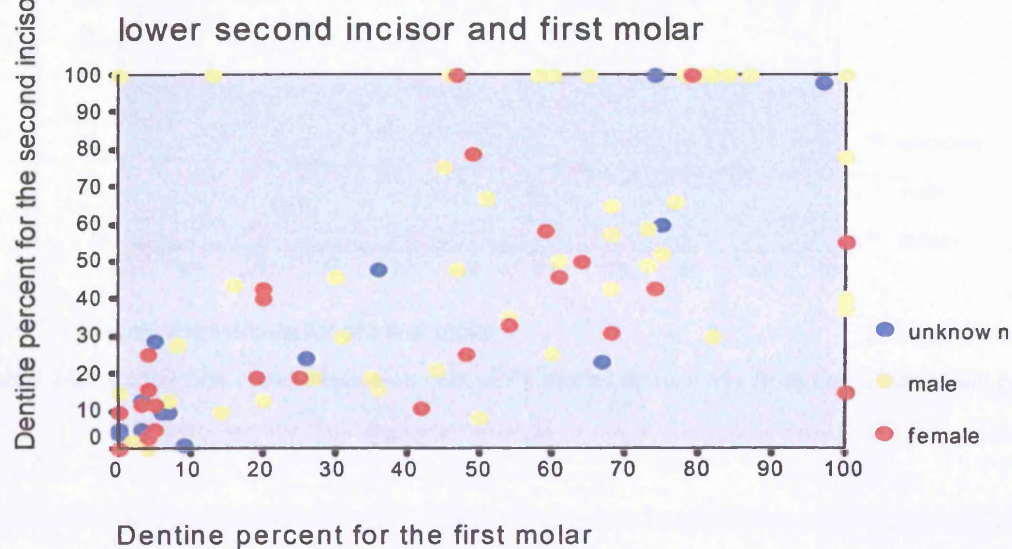


Figure 7.146: Scatter plot of the dentine percent of I2 plotted against M1 from the different sex groups.

## Dentine percent of the males, females and unknown sexed individuals

lower canine and first molar

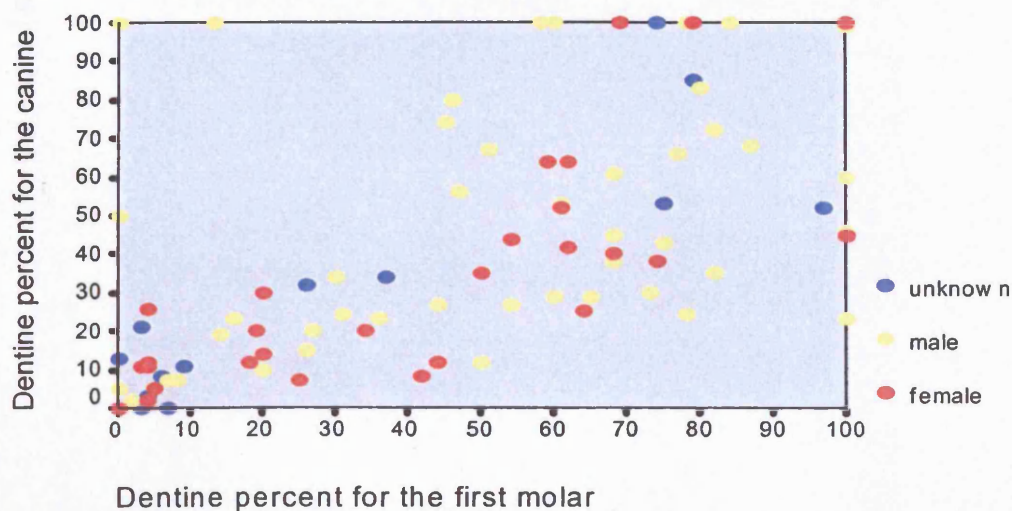


Figure 7.147: Scatter plot of the dentine percent of C plotted against M1 from the different sex groups.

## Dentine percent of the males, females and unknown sexed individuals

lower first premolar and first molar

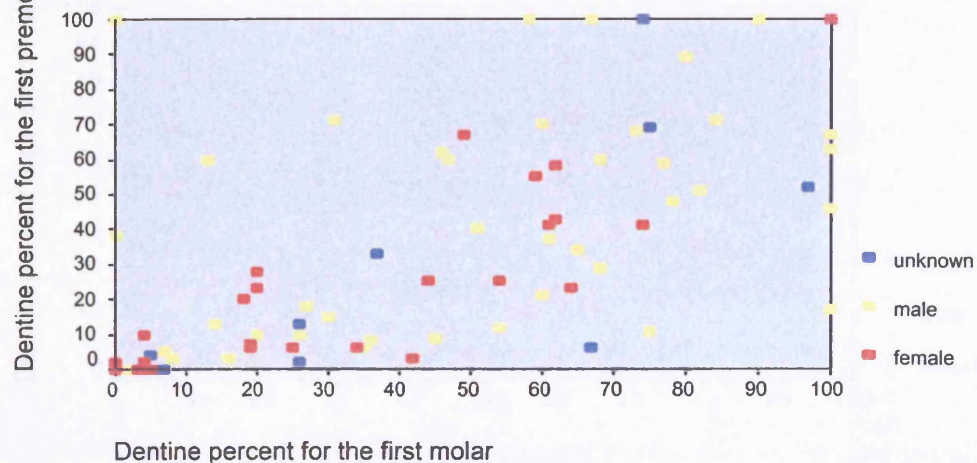


Figure 7.148: Scatter plot of the dentine percent of P1 plotted against M1 from the different sex groups.



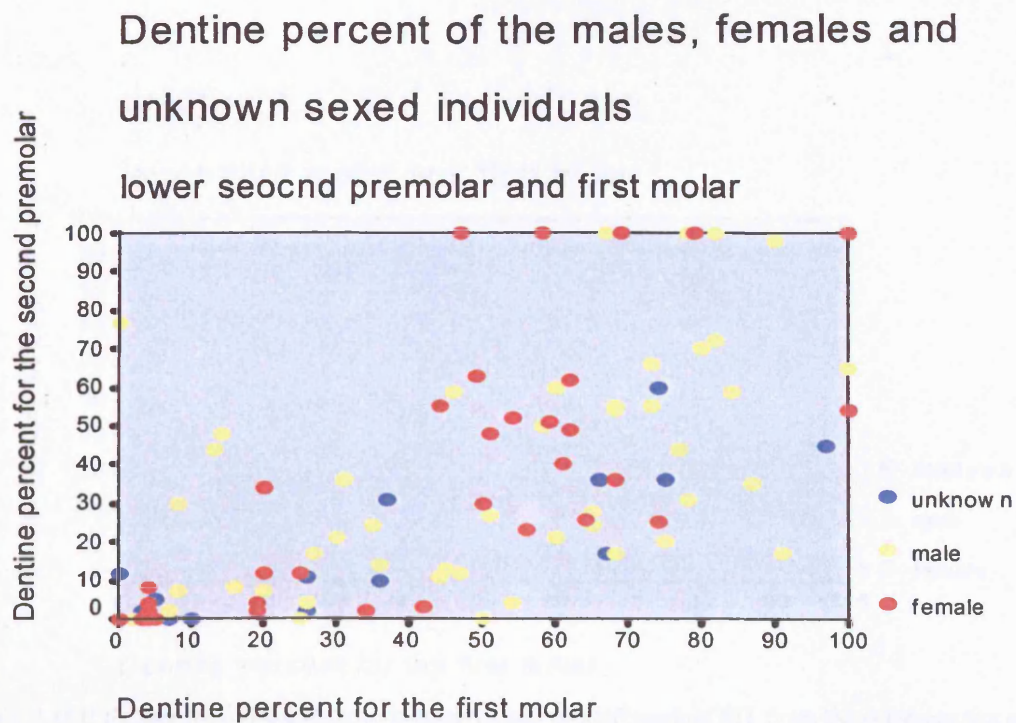


Figure 7.149: Scatter plot of the dentine percent of P2 plotted against M1 from the different sex groups.

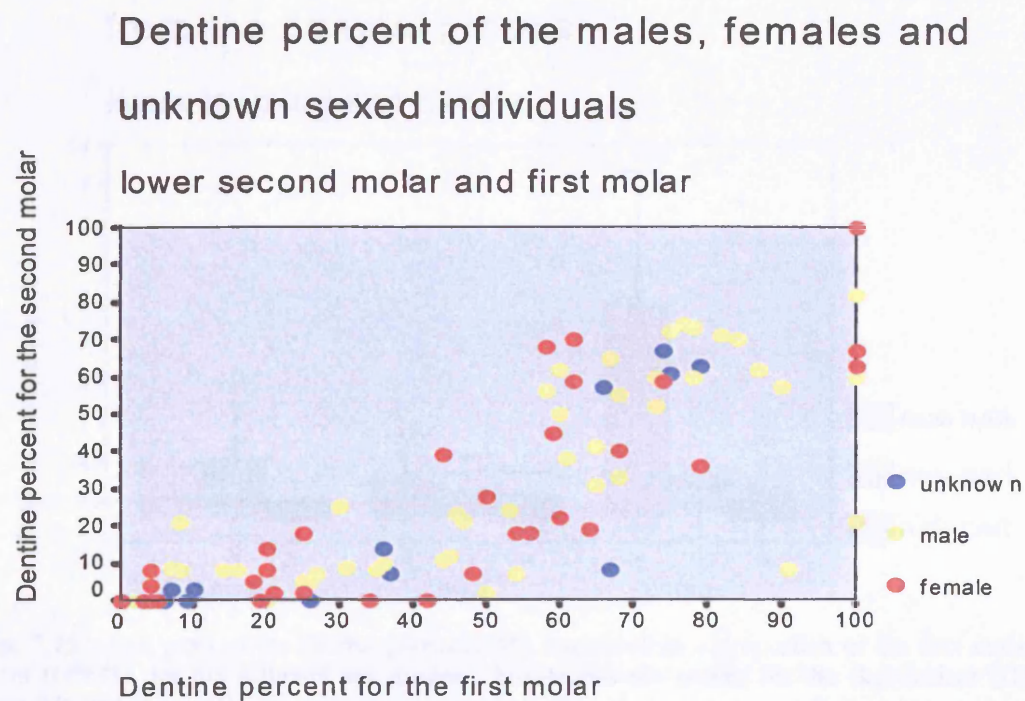


Figure 7.150: Scatter plot of the dentine percent of M2 plotted against M1 from the different sex groups.

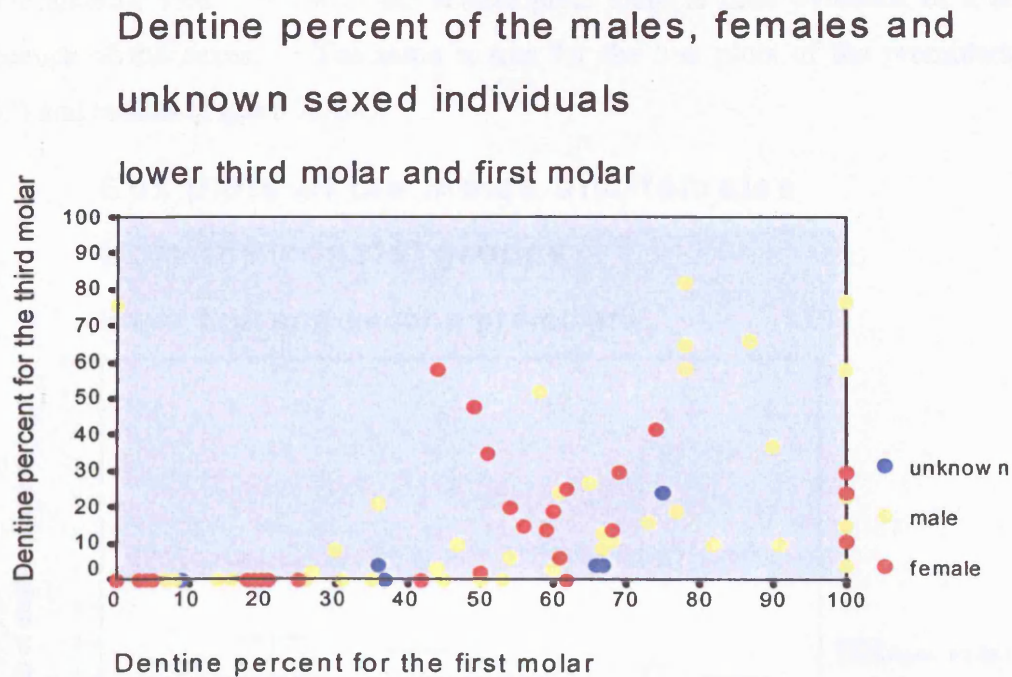


Figure 7.151: Scatter plot of the dentine percent of M3 plotted against M1 from the different sex groups.

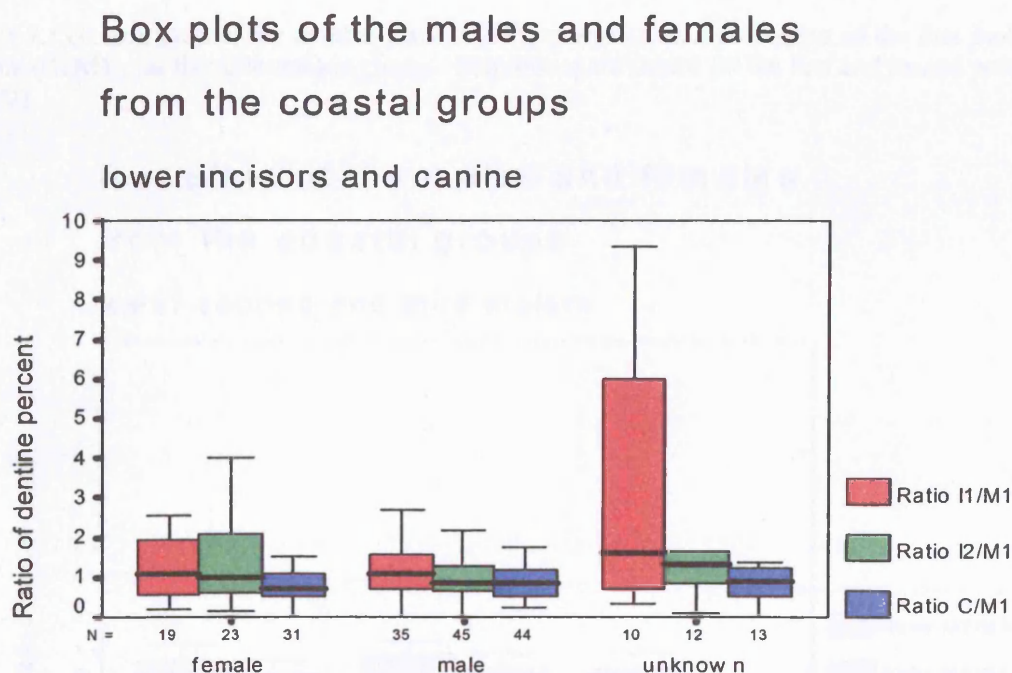


Figure 7.152: Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the different sex groups. Proportions are shown for the first incisor (I1), second incisor (I2), and canine (C).

As in the full collection (Figure 7.45) and full collection sex differences (Figure 7.82) the interquartile and median ratios decrease from I1, to I2 to C. This pattern is repeated in the coastal females, males and unknown sexed individuals, with very little difference between them. The interquartile range is, however, greater in the unknown sex group than the female and male groups. The median ratio of I1 is slightly higher in the unknown sex assemblage but the male and female groups have similar median values for



all the anterior teeth. As with the scatter plots there is little evidence of a consistent difference of the sexes. The same is true for the box plots of the premolars (Figure 7.153) and molars (Figure 7.154).

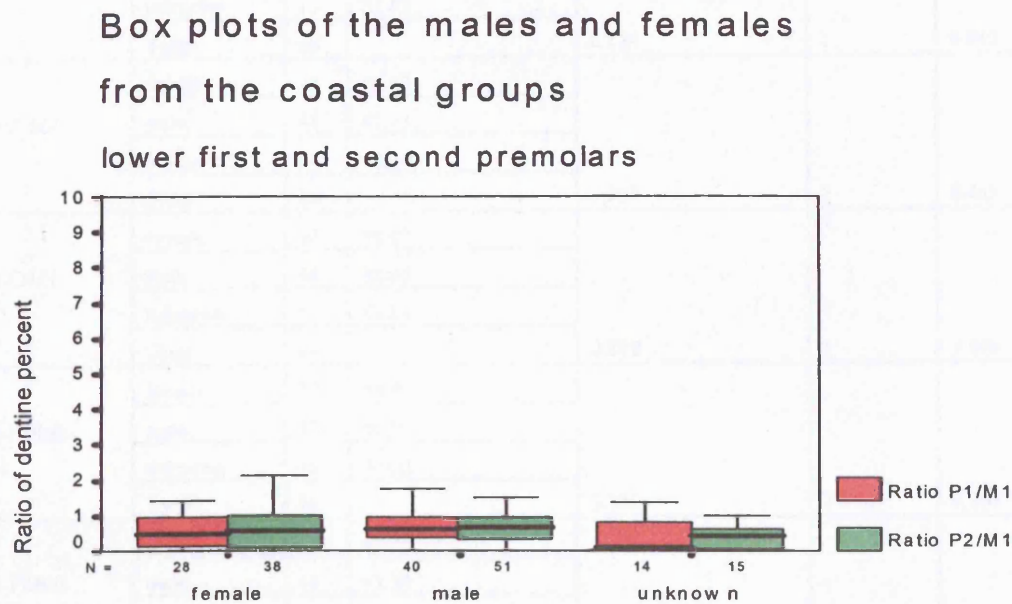


Figure 7.153: Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the different sex groups. Proportions are shown for the first and second premolars (P1 and P2).

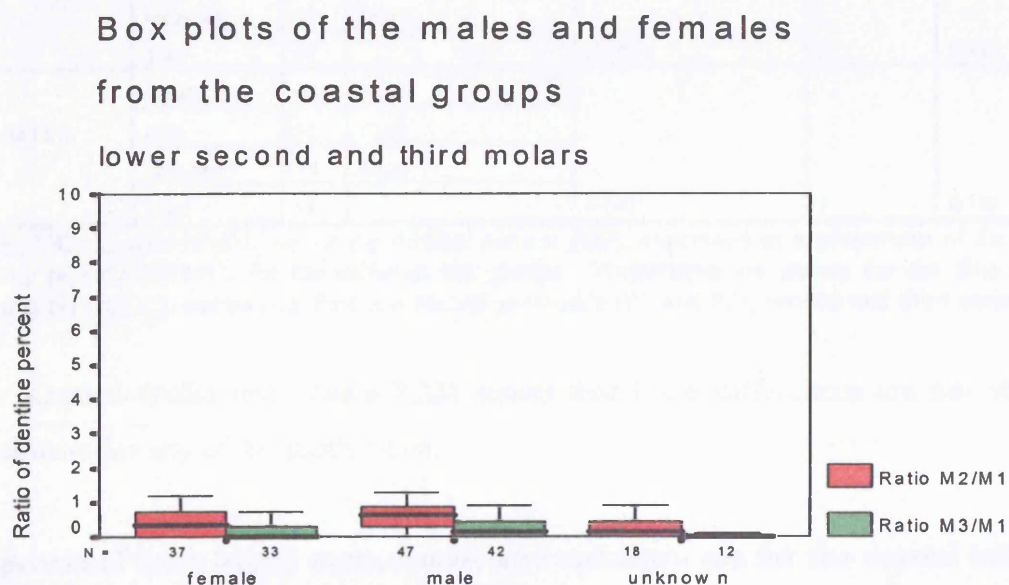


Figure 7.154: Box plots of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the different sex groups. Proportions are shown for the second and third molars (M2 and M3).

**Kruskal-Wallis test dentine percent ratios**

	SEX	N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Ratio I1/M1	female	23	34.61	0.124	2	0.940
	male	30	33.73			
	unknown	15	35.87			
	Total	68				
Ratio I2/M1	female	26	46.65	1.531	2	0.465
	male	41	41.13			
	unknown	21	48.40			
	Total	88				
Ratio C/M1	female	30	48.07	0.812	2	0.666
	male	44	42.90			
	unknown	15	45.03			
	Total	89				
Ratio P1/M1	female	29	46.05	3.133	2	0.209
	male	33	40.59			
	unknown	19	34.00			
	Total	81				
Ratio P2/M1	female	31	45.73	0.315	2	0.839
	male	41	49.35			
	unknown	22	46.55			
	Total	94				
Ratio M2/M1	female	36	45.33	3.027	2	0.220
	male	40	47.43			
	unknown	21	58.29			
	Total	97				
Ratio M3/M1	female	26	32.33	6.643	2	0.360
	male	32	32.92			
	unknown	12	49.25			
	Total	70				

Table 7.32: Kruskal-Wallis test of the dentine percent (DP), expressed as a proportion of the first molar dentine percent (DPM1), for the different sex groups. Proportions are shown for the first and second incisors (I1 and I2), canine (C), first and second premolars (P1 and P2), second and third molars (M2 and M3).

The Kruskal-Wallis test (Table 7.32) shows that these differences are not statistically significant for any of the tooth ratios.

### **Approximal facet length male, female and unknown sex for the coastal behavioural groups**

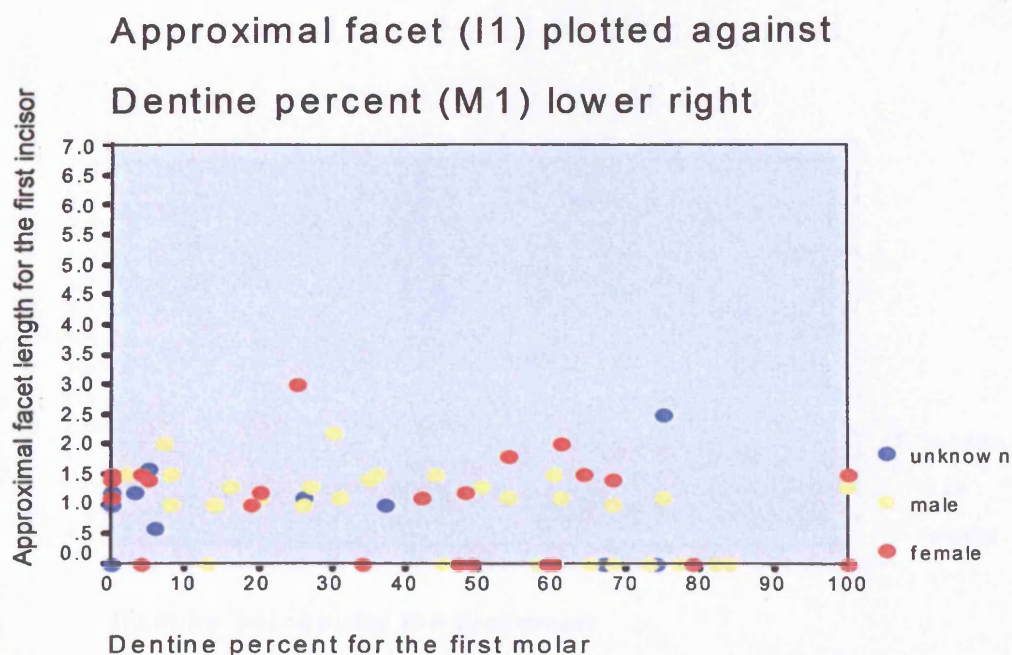


Figure 7.155 Scatter plot of the approximal facet length (mm) of lower right I1 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

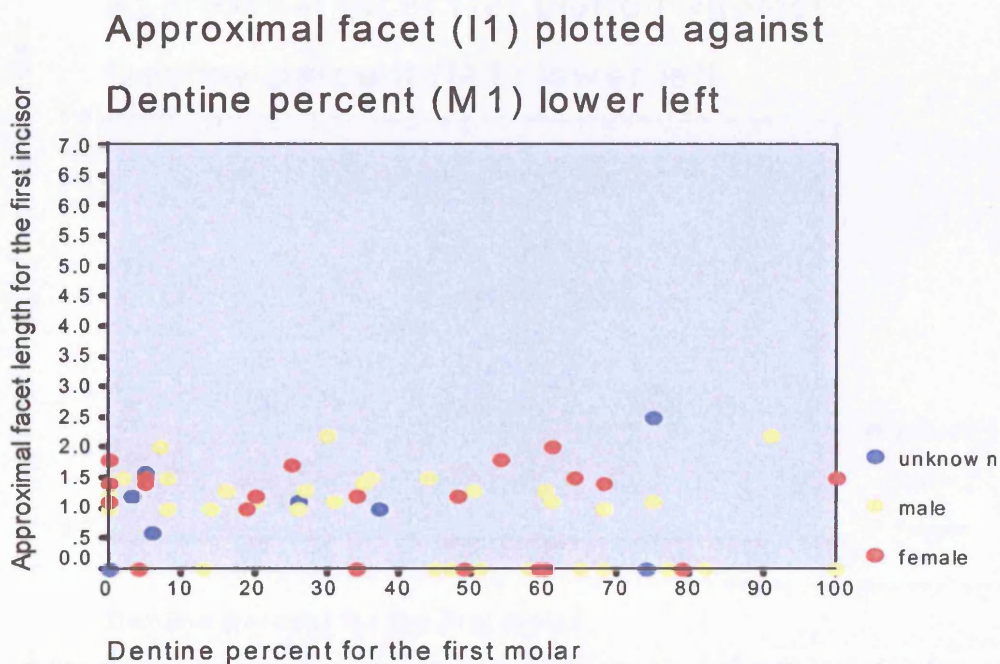


Figure 7.156: Scatter plot of the approximal facet length (mm) of lower left I1 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

Overall, the scatter plots for the approximal facet length plotted against M1 occlusal wear (Figures 7.156-7.170) show a similar sequence of changes from incisors to canines, premolars and molars to that shown in the full collection (Figures 7.50-7.71) and the full collection sex differences (Figures 7.85-7.100). There is extensive overlap between male, female and unknown sex scatters with little evidence of a different pattern of approximal wear.



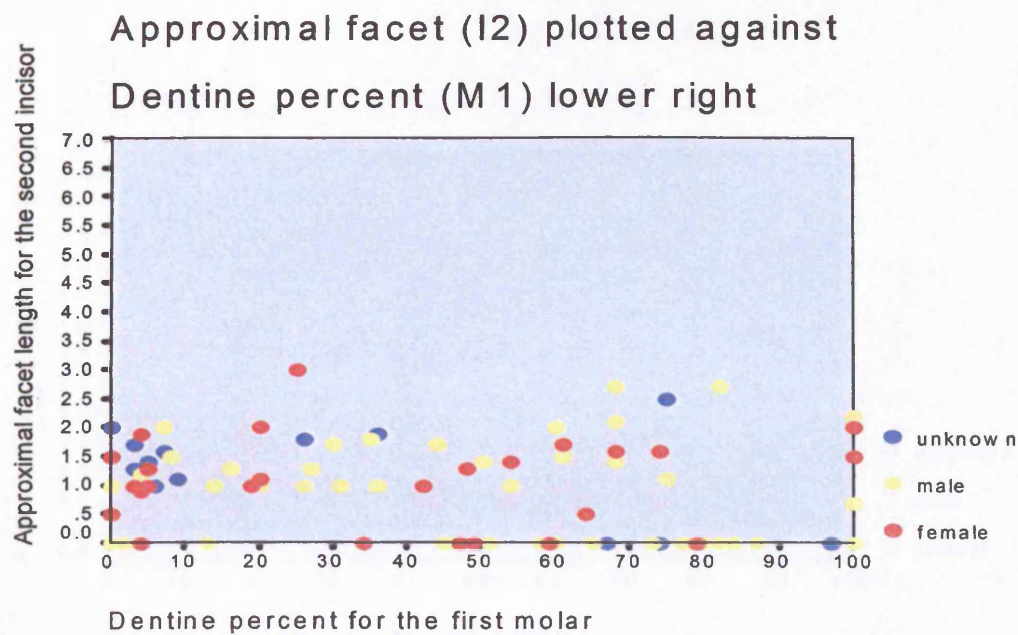


Figure 7.157: Scatter plot of the approximal facet length (mm) of lower right I2 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

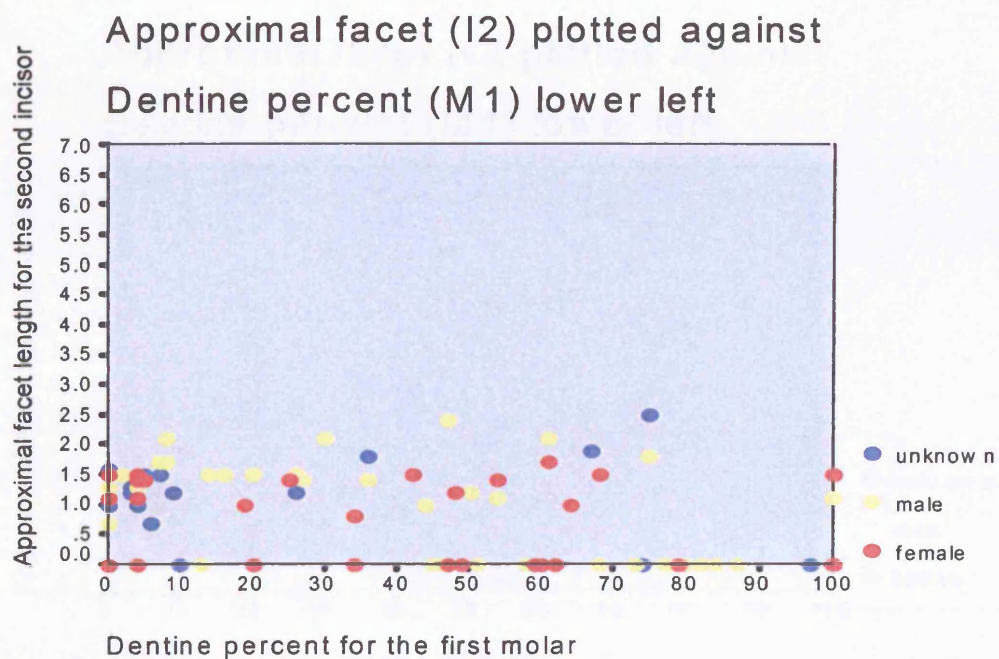


Figure 7.158: Scatter plot of the approximal facet length (mm) of lower left I2 plotted against occlusal wear (dentine percent for M1) for the different sex groups.



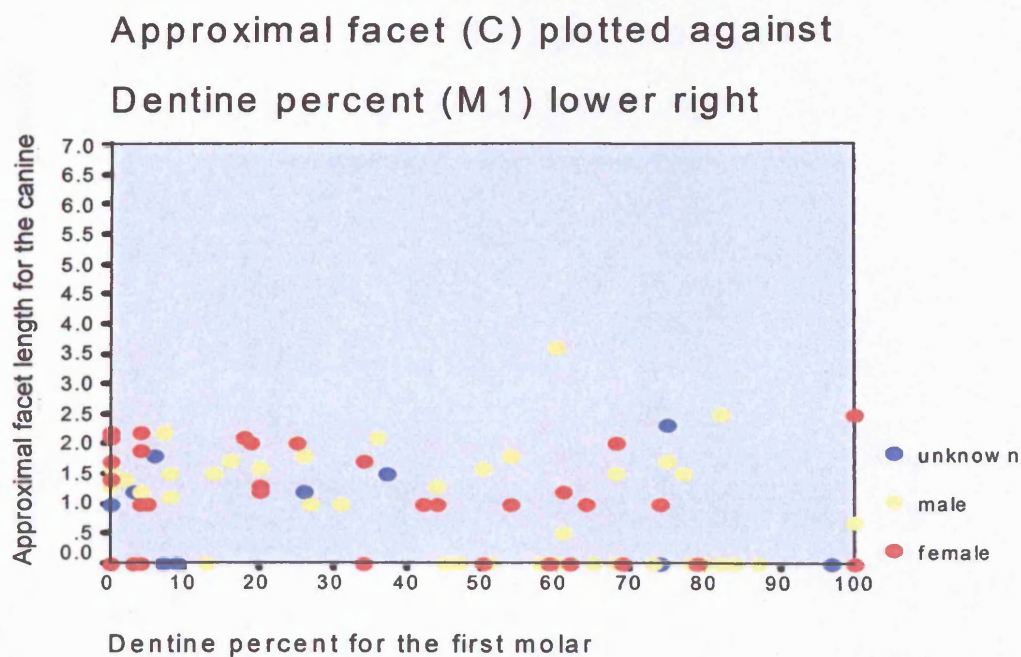


Figure 7.159: Scatter plot of the approximal facet length (mm) of lower right C plotted against occlusal wear (dentine percent for M1) for the different sex groups.

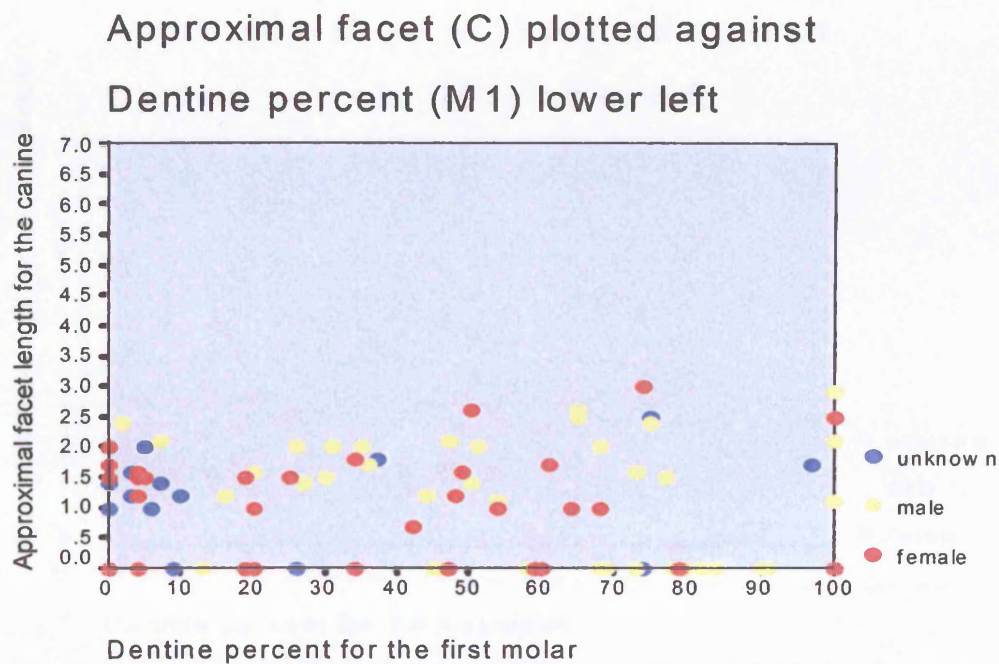


Figure 7.160: Scatter plot of the approximal facet length (mm) of lower left C plotted against occlusal wear (dentine percent for M1) for the different sex groups.

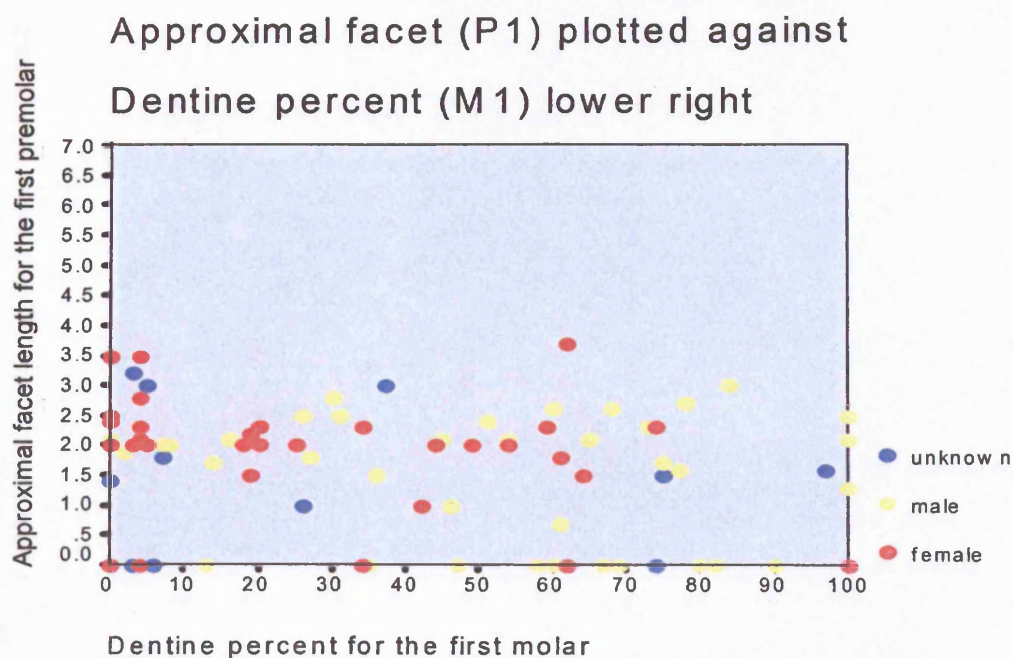


Figure 7.161: Scatter plot of the approximal facet length (mm) of lower right P1 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

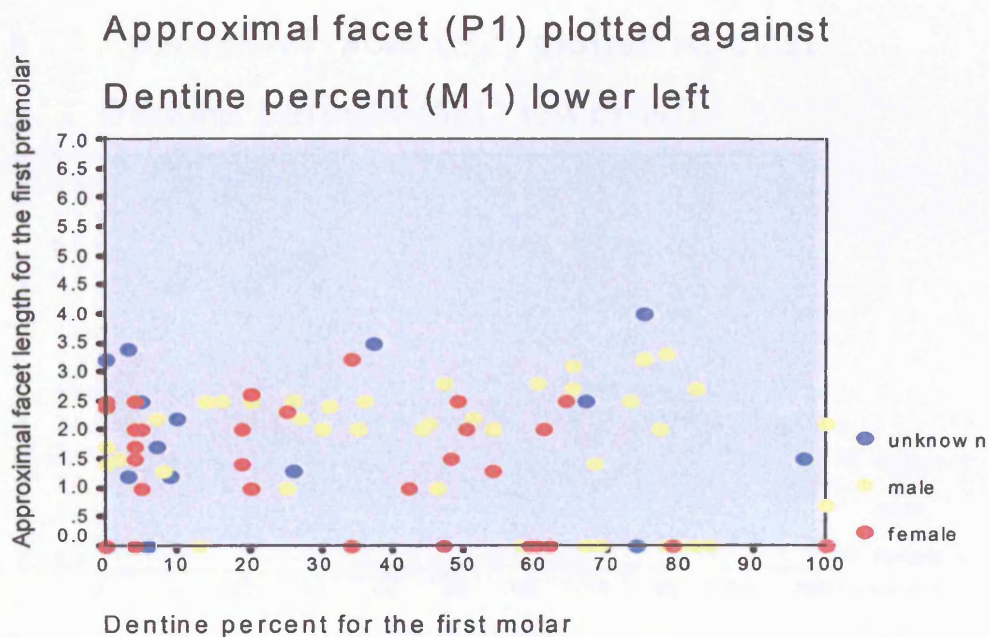


Figure 7.162: Scatter plot of the approximal facet length (mm) of lower left P1 plotted against occlusal wear (dentine percent for M1) for the different sex groups.



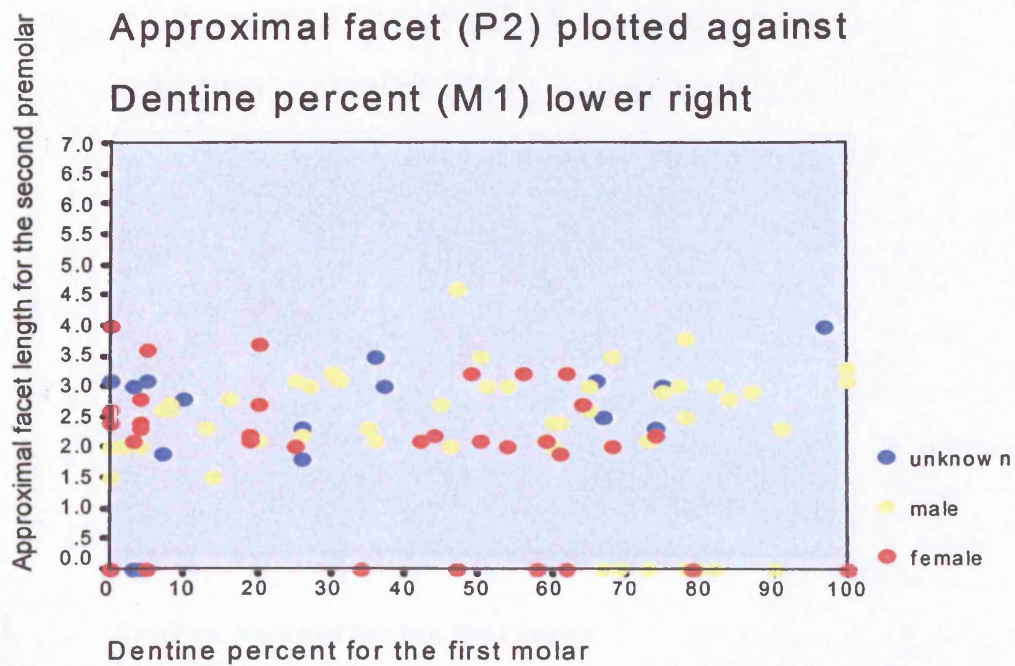


Figure 7.163: Scatter plot of the approximal facet length (mm) of lower right P2 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

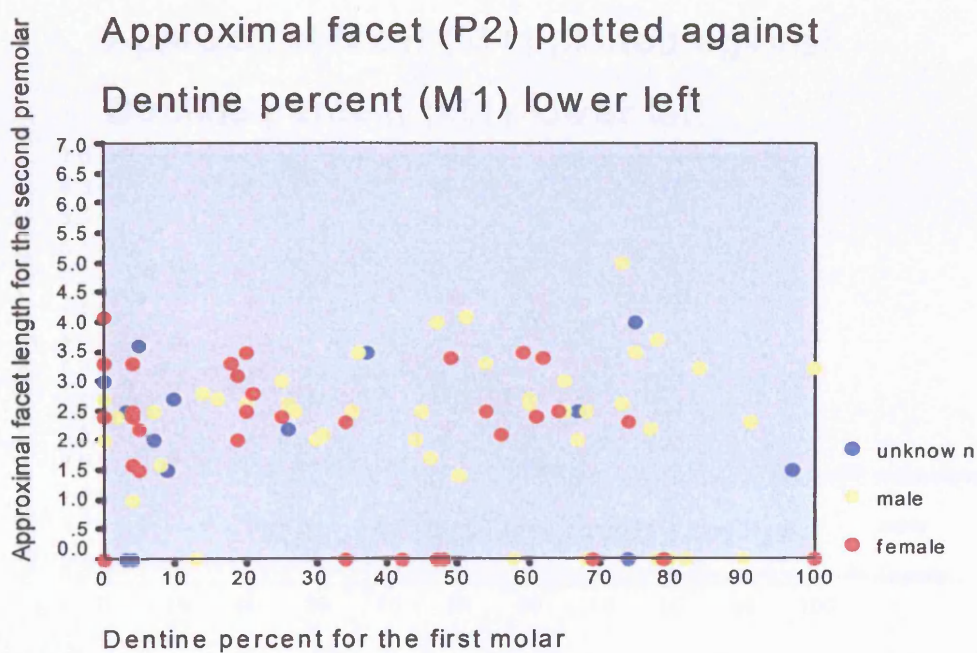


Figure 7.164: Scatter plot of the approximal facet length (mm) of lower left P2 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

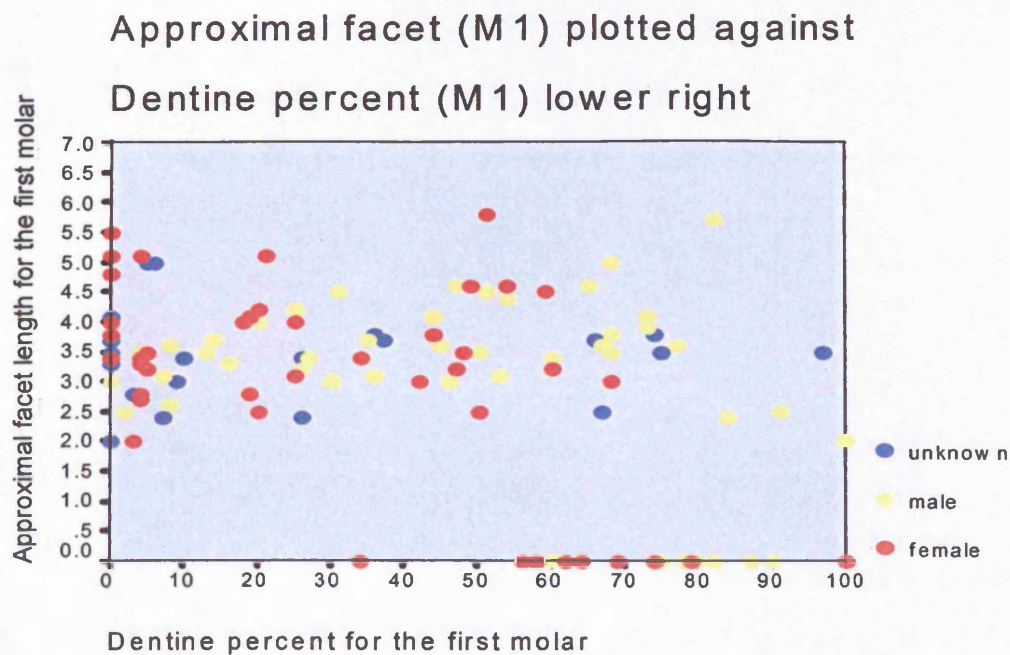


Figure 7.165: Scatter plot of the approximal facet length (mm) of lower right M1 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

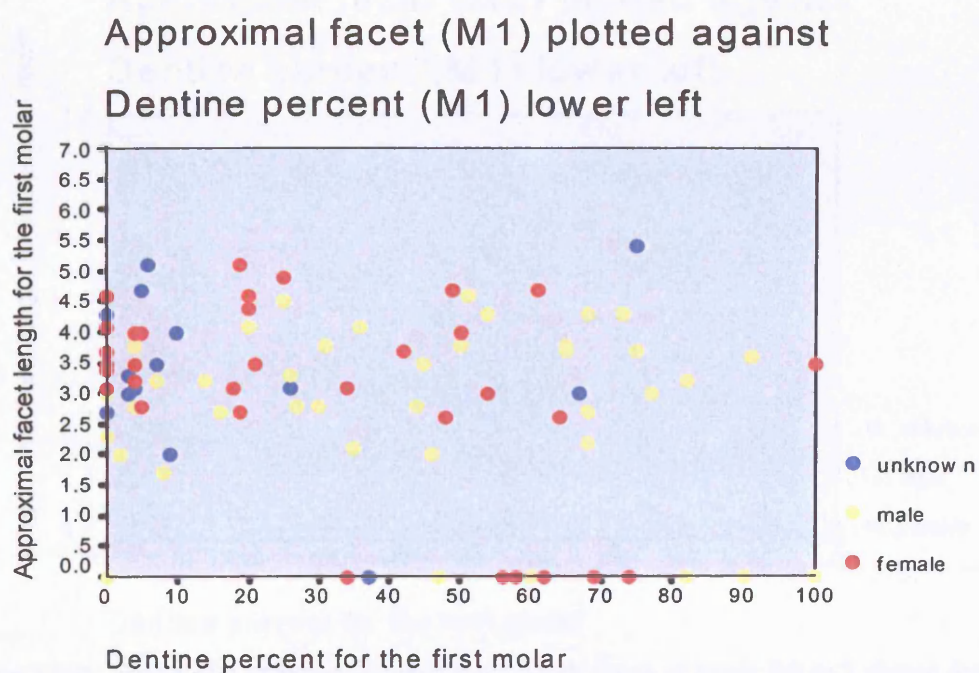


Figure 7.166: Scatter plot of the approximal facet length (mm) of lower left M1 plotted against occlusal wear (dentine percent for M1) for the different sex groups.



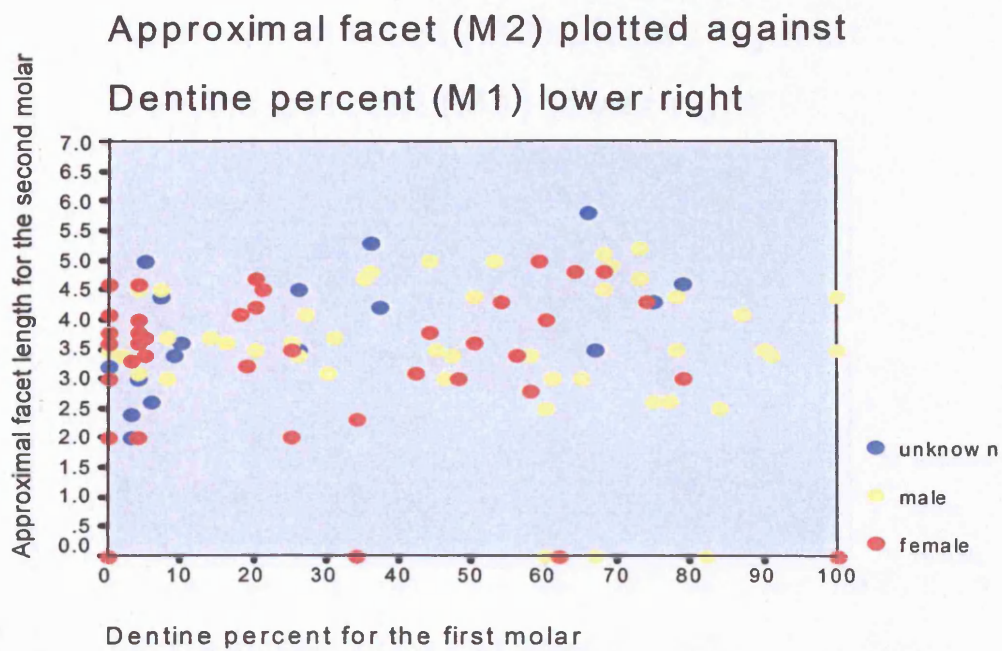


Figure 7.167: Scatter plot of the approximal facet length (mm) of lower right M2 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

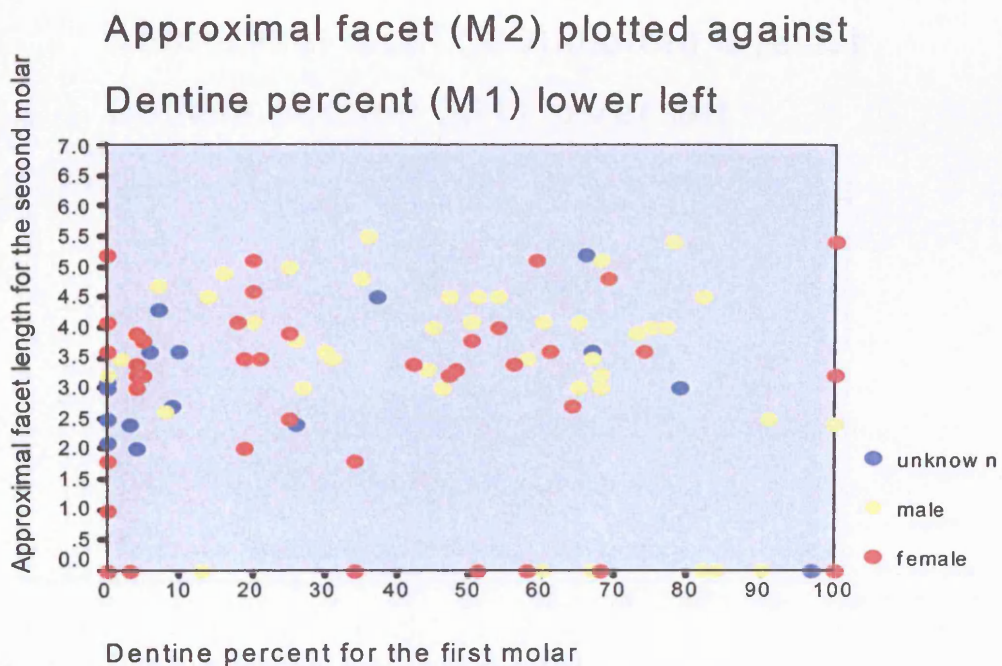


Figure 7.168: Scatter plot of the approximal facet length (mm) of lower left M2 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

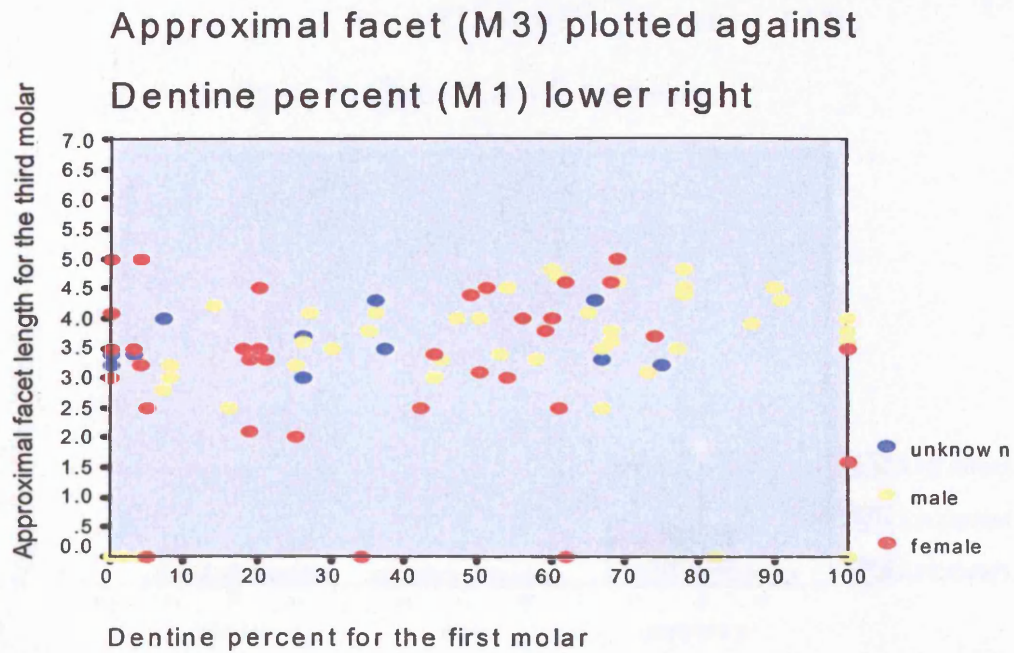


Figure 7.169: Scatter plot of the approximal facet length (mm) of lower right M3 plotted against occlusal wear (dentine percent for M1) for the different sex groups.

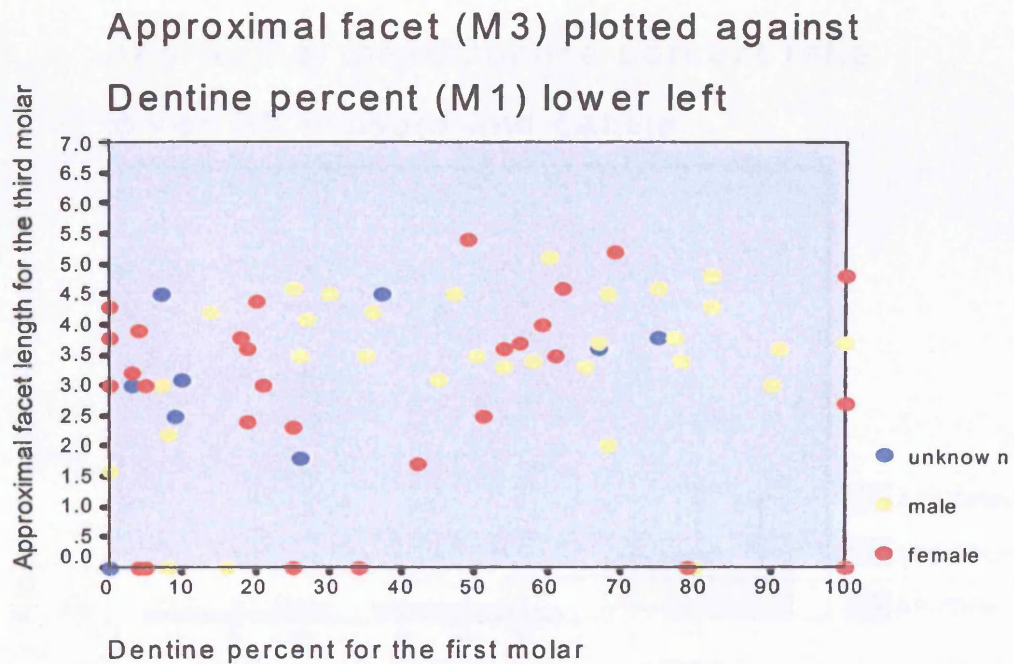


Figure 7.170: Scatter plot of the approximal facet length (mm) of lower right M3 plotted against occlusal wear (dentine percent for M1) for the different sex groups.



### Approximal facet/Dentine percent ratio lower right incisors and canine

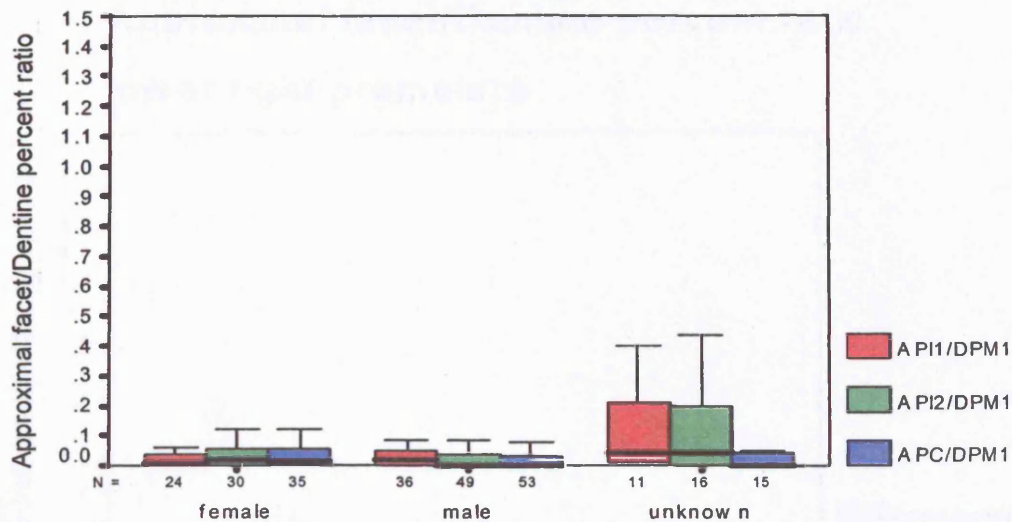


Figure 7.171: Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups. Proportions are shown for the lower right first incisor (I1), second incisor (I2), and canine (C).

### Approximal facet/Dentine percent ratio lower left incisors and canine

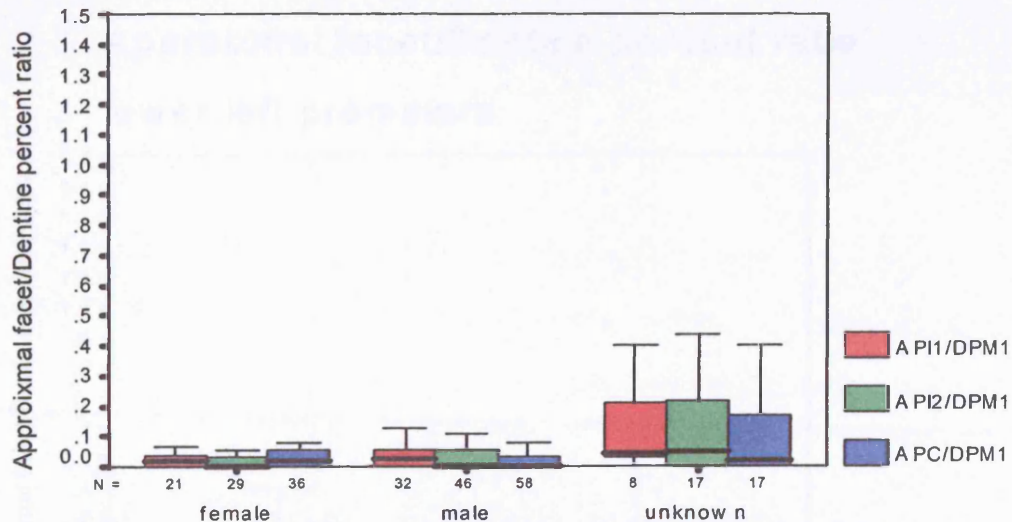


Figure 7.172: Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups. Proportions are shown for the lower left first incisor (I1), second incisor (I2), and canine (C).

As in the full collection sex differences (Figures 7.101-7.106), the box plots of the sex differences between coastal groups approximal facet/dentine percent ratio (Figures 7.172-7.176) shows greater interquartile ranges and overall ranges of the unknown sexed group. In I1, I2 and C there is very little difference between male and female groups. For premolars (Figures 7.173-7.174) and molars (Figures 7.175 and 7.176) the male and

female medians are similar but the females have larger interquartile ranges and overall ranges than the males.

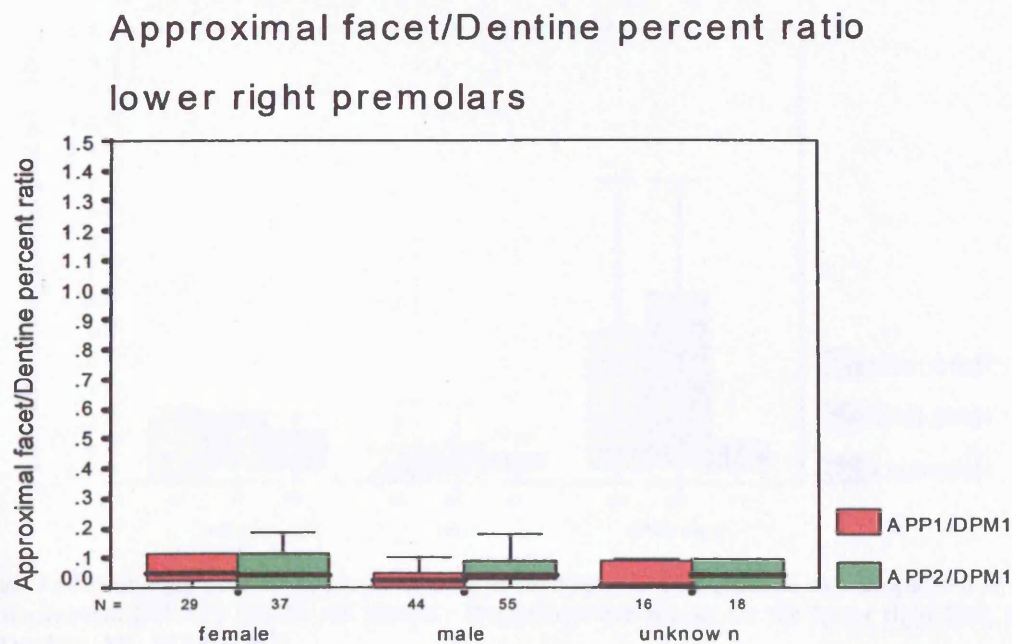


Figure 7.173: Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups. Proportions are shown for the lower right first and second premolars (P1 and P2).

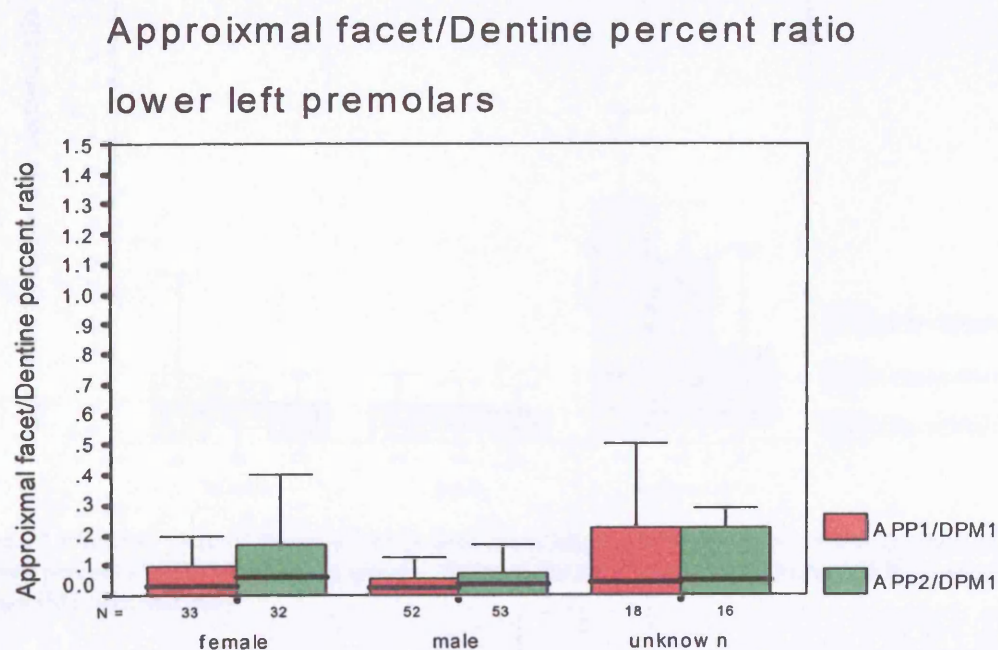


Figure 7.174: Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups. Proportions are shown for the lower left first and second premolars (P1 and P2).



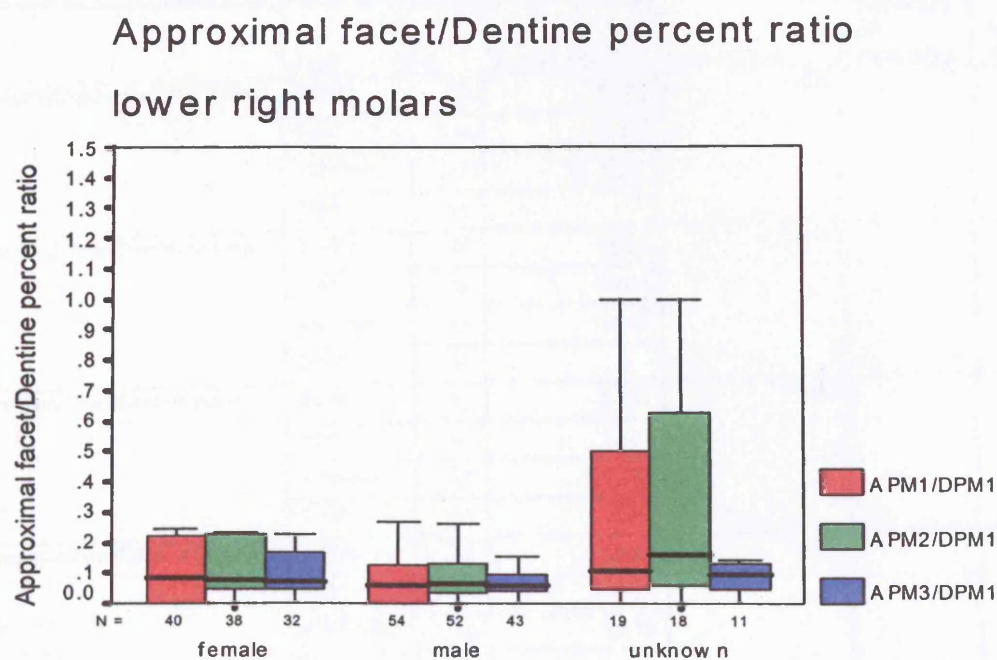


Figure 7.175: Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups. Proportions are shown for the lower right first, second and third molars (M1, M2 and M3).

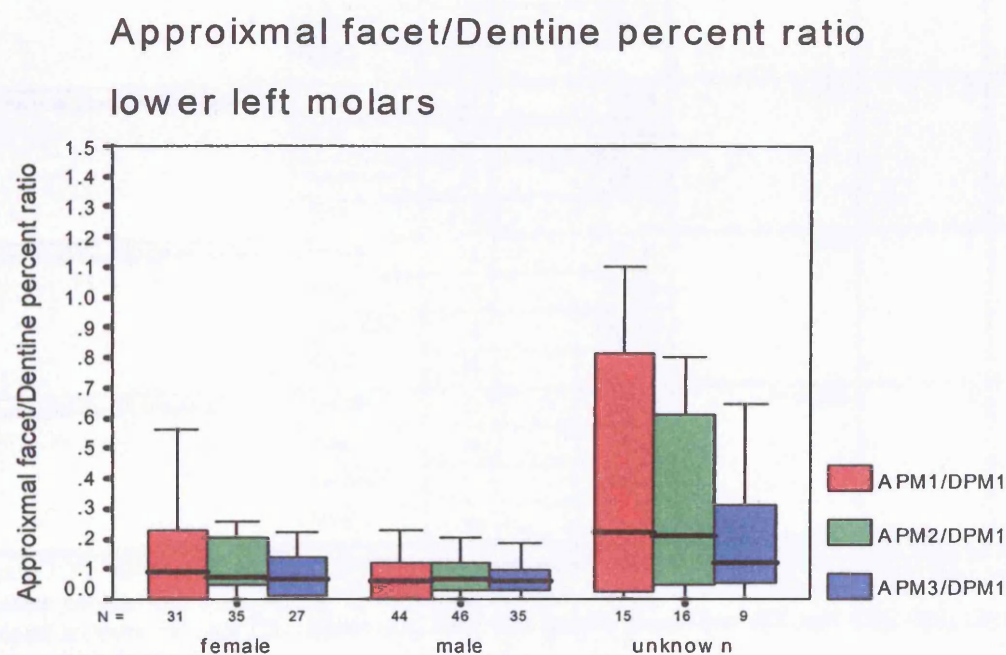


Figure 7.176: Box plots of the approximal wear facet length (AP) expressed as a proportion of first molar dentine percent (DPM1) for the sex groups. Proportions are shown for the lower left first, second and third molars (M1, M2 and M3).

## Kruskal-Wallis lower right

	SEX	N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/Dentine percent I1	female	24	31.94	3.728		0.155
	male	36	35.68			
	unknown	11	45.91			
	Total	71				
Approximal facet/Dentine percent I2	female	30	50.13	3.044		0.218
	male	49	43.94			
	unknown	16	56.44			
	Total	95				
Approximal facet/Dentine percent C	female	35	54.34	0.434		0.805
	male	53	50.42			
	unknown	15	52.13			
	Total	103				
Approximal facet/Dentine percent P1	female	29	53.24	4.622	2	0.099
	male	44	41.47			
	unknown	16	39.78			
	Total	89				
Approximal facet/Dentine percent P2	female	37	54.80	0.192	2	0.908
	male	55	55.00			
	unknown	18	58.47			
	Total	110				
Approximal facet/Dentine percent M1	female	40	58.66	4.319	2	0.115
	male	54	51.49			
	unknown	19	69.16			
	Total	113				
Approximal facet/Dentine percent M2	female	38	57.37	7.067	2	0.129
	male	52	47.32			
	unknown	18	69.19			
	Total	108				
Approximal facet/Dentine percent M3	female	32	46.41	1.552	2	0.460
	male	43	40.19			
	unknown	11	48.00			
	Total	86				

Table 7.33: Kruskal-Wallis test of the approximal wear (AP), expressed as a proportion of the first molar dentine percent (DPM1), for the different sex groups. Proportions are shown for the lower right first and second incisors (I1 and I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2 and M3).

**Kruskal-Wallis lower left**

	SEX	N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/Dentine percent I1	female	21	27.62	4.4247	2	0.120
	male	32	30.39			
	unknown	8	42.31			
	Total	61				
Approximal facet/Dentine percent I2	female	29	44.71	4.419	2	0.110
	male	46	43.42			
	unknown	17	57.88			
	Total	92				
Approximal facet/Dentine percent C	female	36	58.86	2.886	2	0.236
	male	58	51.76			
	unknown	17	64.41			
	Total	111				
Approximal facet/Dentine percent P1	female	33	53.30	1.524	2	0.476
	male	52	48.97			
	unknown	18	58.36			
	Total	103				
Approximal facet/Dentine percent P2	female	32	56.16	1.934	2	0.380
	male	53	47.36			
	unknown	16	52.75			
	Total	101				
Approximal facet/Dentine percent M1	female	31	47.50	4.175	2	0.124
	male	44	40.58			
	unknown	15	55.80			
	Total	90				
Approximal facet/Dentine percent M2	female	35	49.94	3.363	2	0.162
	male	46	44.50			
	unknown	16	59.88			
	Total	97				
Approximal facet/Dentine percent M3	female	27	36.17	3.482	2	0.175
	male	35	32.97			
	unknown	9	47.28			
	Total	71				

Table 7.34: Kruskal-Wallis test of the approximal wear (AP), expressed as a proportion of the first molar dentine percent (DPM1), for the different sex groups. Proportions are shown for the lower left first and second incisors (I1 and I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2 and M3).

The Kruskal-Wallis tests (Tables 7.33 and 7.34) confirm that there are no statistically significant differences in any of the ratios between the coastal sex group assemblages.

### **Occlusal angle measurement male, female and unknown sex for the coastal behavioural groups**

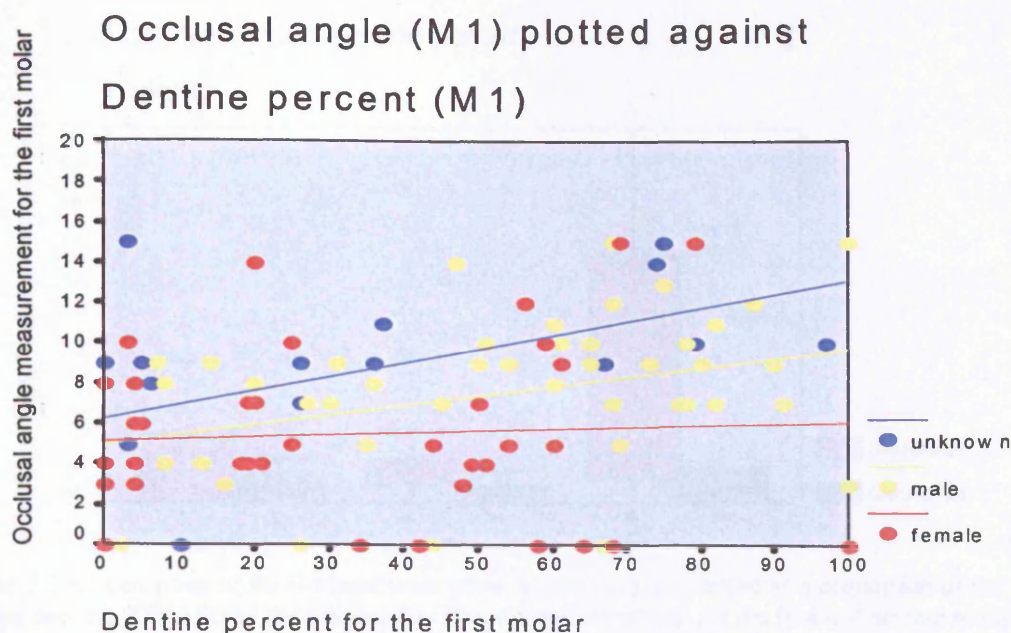


Figure 7.177: Scatter plot of M1 occlusal angle plotted against M1 occlusal wear (dentine percent), for different sex groups.

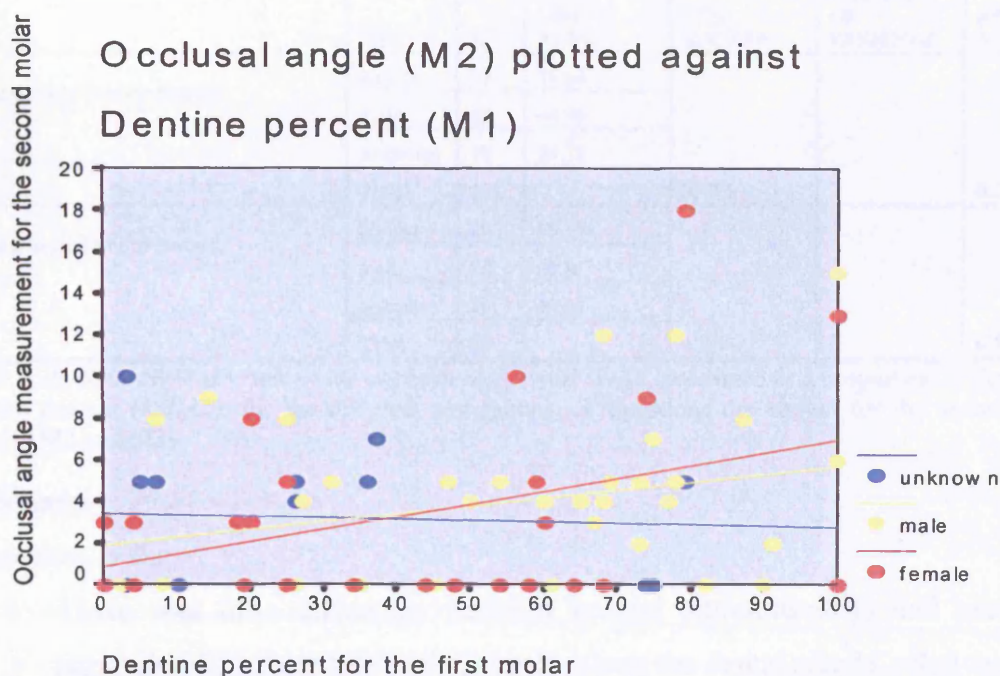


Figure 7.178: Scatter plot of M2 occlusal angle plotted against M1 occlusal wear (dentine percent), for different sex groups.

Similar to the full collection scatter plots of the occlusal angle wear (Figures 7. 7.107 and 7.108) the coastal groups (Figures 7.176 and 7.177) show extensive overlap between the males, females and unknown sex individuals. The box plot (Figure 7.179) of the occlusal angle/dentine percent ratios also show only small differences between medians of the males and females. The interquartile range of females is slightly higher than the males and the range of the unknown sex individuals is markedly higher than either the known sex groups. These differences are also not statistically significant (Table 7.35).



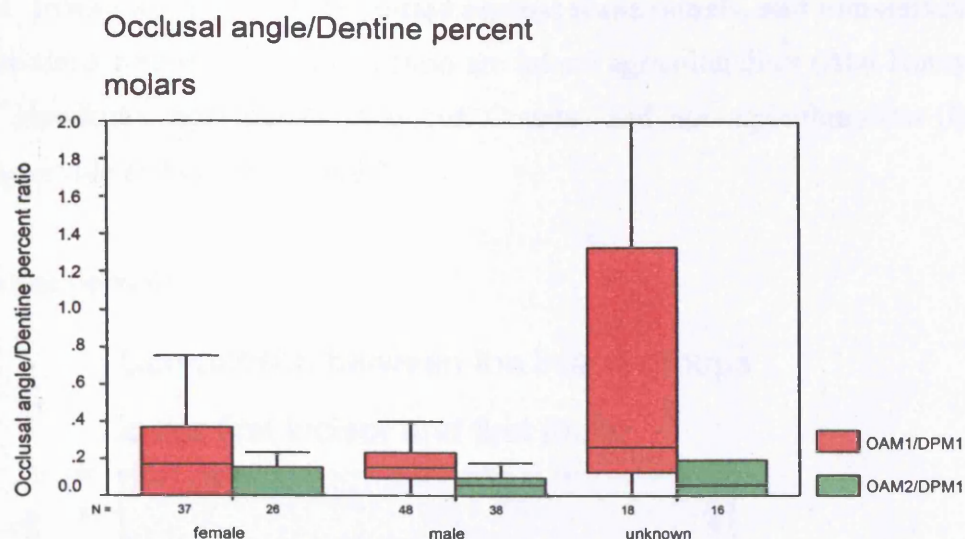


Figure 7.179: Box plots of the occlusal wear plane angle (OA), expressed as a proportion of the first molar dentine percent (DPM1), for the sex groups. Proportions are shown for the first and second molars (M1 and M2).

#### Kruskal-Wallis

	SEX	N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Occlusal angle/Dentine percent M1	female	37	50.04	3.754	2	0.153
	male	48	48.90			
	unknown	18	64.31			
	Total	103				
Occlusal angle/Dentine percent M2	female	26	37.19	1.042	2	0.594
	male	38	41.24			
	unknown	16	44.13			
	Total	80				

Table 7.35: Kruskal-Wallis test of the occlusal angle wear (OA), expressed as a proportion of the first molar dentine percent (DPM1), for the different sex groups. Proportions are shown for the second and third molars (M2 and M3).

#### Summary

These results show:

1. There was little difference between coastal agriculturalists and coastal non-agriculturalists pattern of occlusal wear along the dental arcade, relative to M1.
2. There was similarly little difference between coastal agriculturalists and coastal non-agriculturalists pattern of approximal facet length along the dental arcade, relative to M1 occlusal wear.
3. Coastal non-agriculturalists had larger molar occlusal wear facet angles for any given stage of M1 occlusal wear than coastal agriculturalists.
4. The coastal collections did not show a significant difference between the males, females and unknown sex individuals for any aspect of the dental wear.

### 7.2.C Inland agriculturalists plotted against transitionals, and non-agriculturalists

Collections compared for this section are inland agriculturalists (Abu Hureyra, Shannon and Hawikuh), transitionals (Calhoun County) and non-agriculturalists (Indian Knoll, Chiggerville and Carlston Annis).

#### Dentine percent

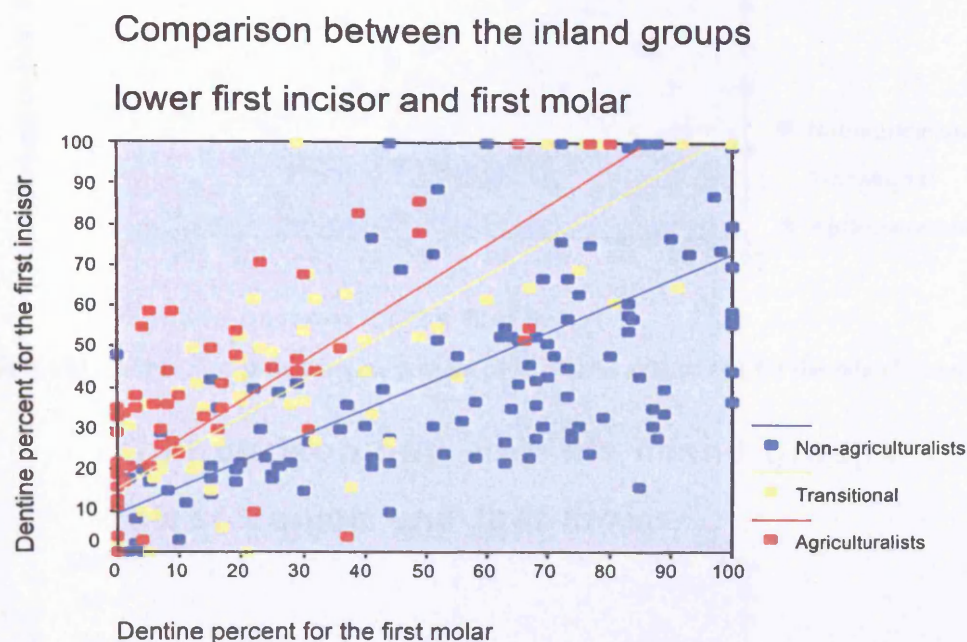


Figure 7.180: Scatter plot of the dentine percent on I1 plotted against M1 for the inland groups.

Similar to the full collection (Figure 7.40) the inland behavioural groups (Figure 7.180), show a general trend of increasing I1 wear for increasing molar wear, but with a good deal of variation. The scatters of points for all three inland assemblages overlap, but the transitional and agricultural groups overlap to a greater extent than either overlaps with the non-agriculturalists. In addition, the trend of points in the inland transitional and agriculturalist scatters rises more steeply than the inland non-agriculturalists scatter. This implies that I1 wear is generally more advanced for any given stage of M1 occlusal wear in the transitionals and agriculturalists than it is in the non-agriculturalists. This is very similar to the full collection but these differences are more marked in the inland behavioural groups, which contrasts strongly with the coastal behavioural groups.



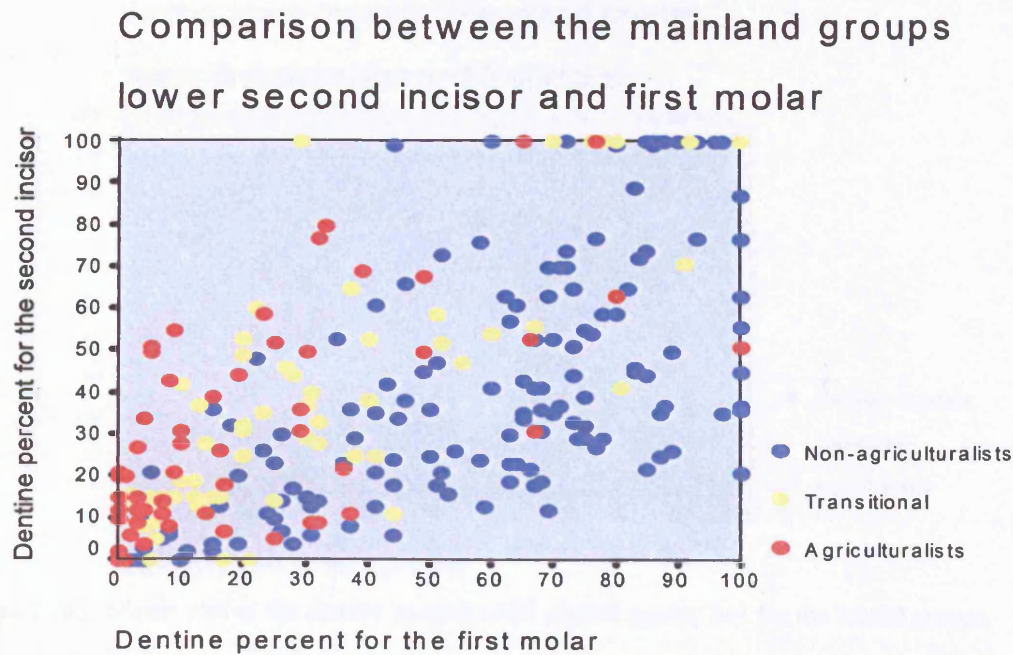


Figure 7.181: Scatter plot of the dentine percent of I2 plotted against M1 for the inland groups.

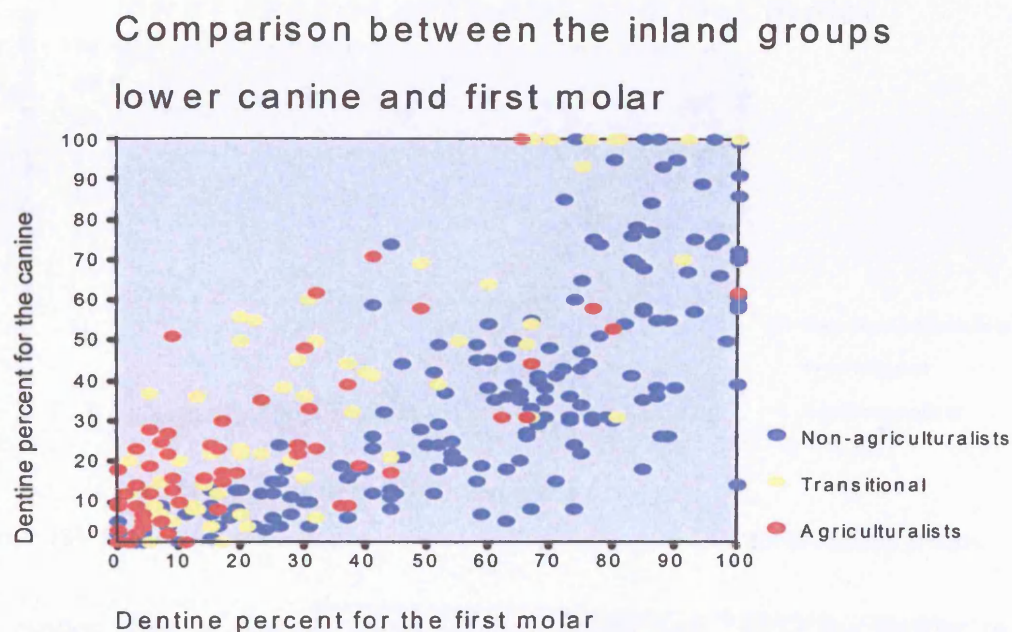


Figure 7.182: Scatter plot of the dentine percent of C plotted against M1 for the inland groups.

The scatter plots I2 and C (Figures 7.181 and 7.182) show a greater degree of variability than I1 with more overlap between the scatters of points for the different inland behavioural assemblages. The transitionals and agriculturalists, however, still show a moderately steeper slope of scatters than the non-agriculturalists.

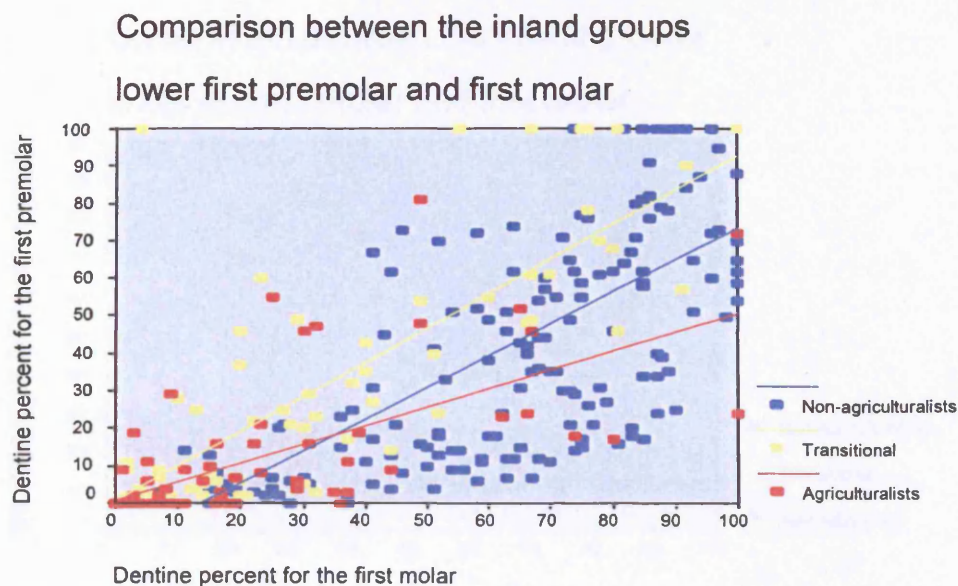


Figure 7.183: Scatter plot of the dentine percent of P1 plotted against M1 for the inland groups.

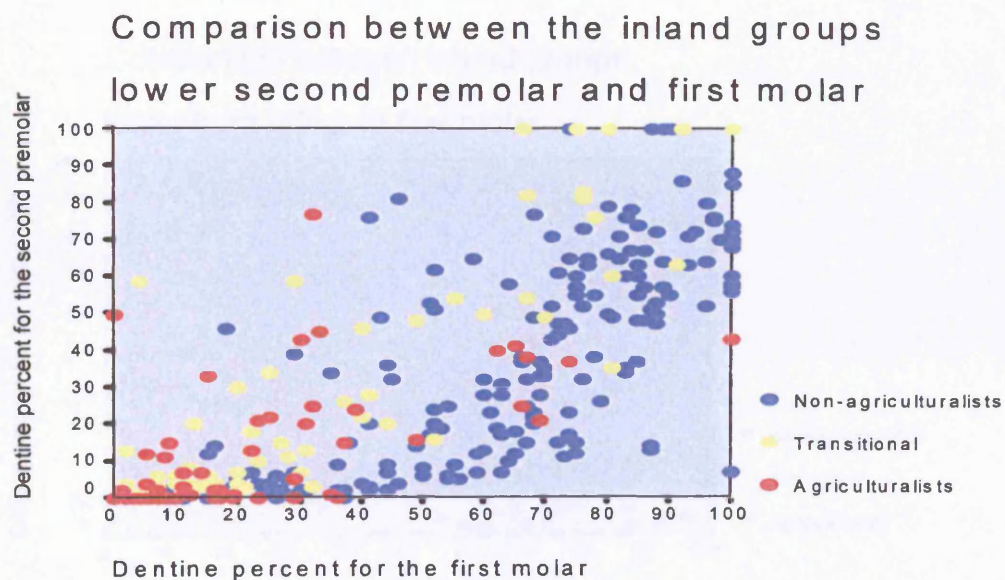


Figure 7.184: Scatter plot of the dentine percent of P2 plotted against M1 for the inland groups.

The scatter plots of the premolars (Figures 7.183 and 7.184) are similar to the full collection (Figures 7.43 and 7.44). The scatters for all three behavioural groups overlap but the non-agriculturalists and agriculturalists overlap to a greater extent than either overlaps with the transitional group. Once more, the transitional group has a steeper slope of scatters than the non-agriculturalists and agriculturalists.



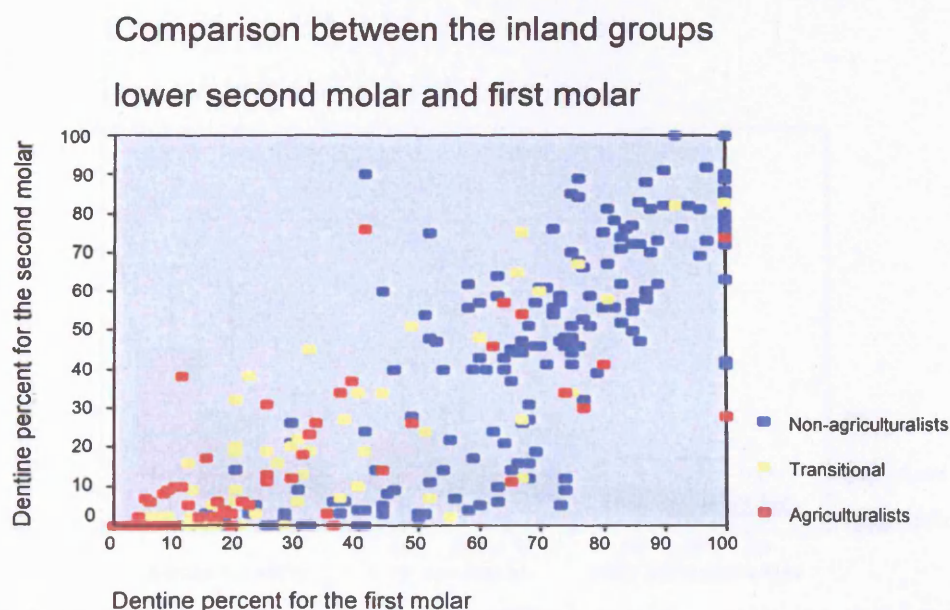


Figure 7.185: Scatter plot of the dentine percent of M2 plotted against M1 for the inland groups.

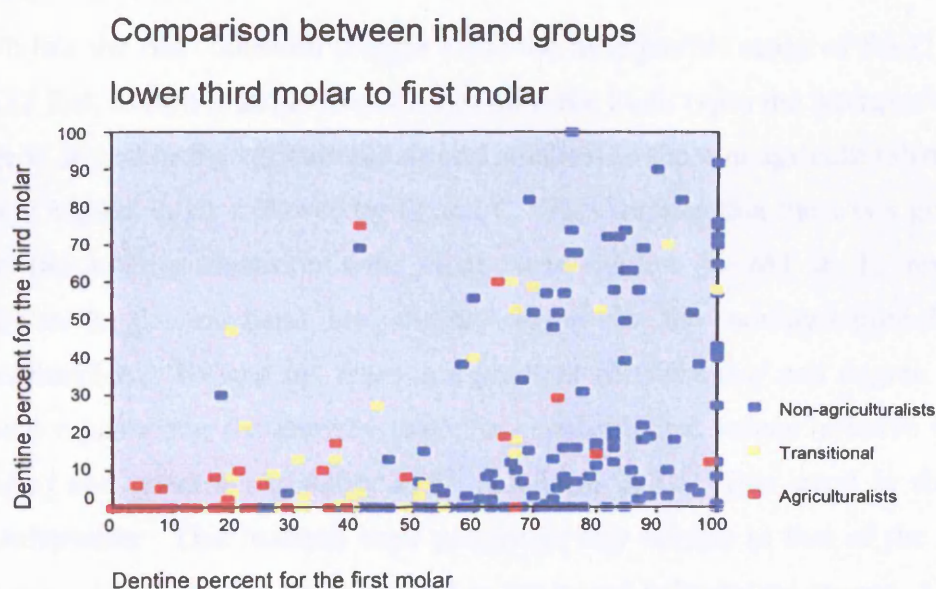


Figure 7.186: Scatter plot of the dentine percent of the lower M3 plotted against the dentine percent on M1 for the inland groups.

In M2 (Figures 7.185) the scatters for the agriculturalists and transitionals overlap one another more than either overlaps with the non-agriculturalists. As with the full collection (Figure 7.46) it can be seen that M3 (Figure 7.186) follows a different pattern with very little wear up to 50% M1 dentine exposure and markedly more wear after that.

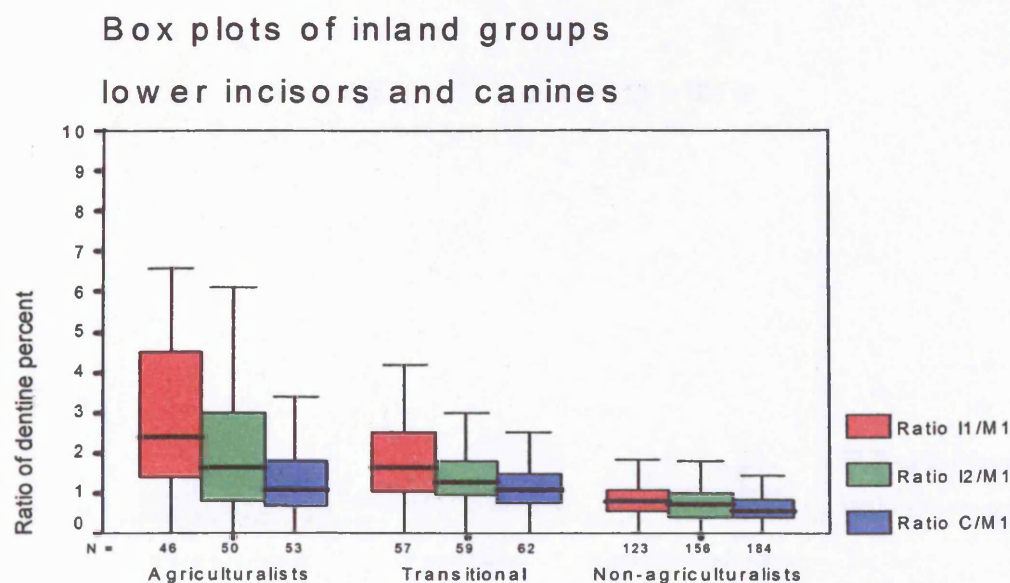


Figure 7.187: Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for inland behavioural groups. Proportions are shown for the first incisor (I1), second incisor (I2), and canine (C).

Much like the full collection (Figure 7.47) the interquartile range of the I1 ratio is larger than I2 that, in turn is larger than C. For all three tooth types the interquartile and overall range is largest in the agriculturalists and smallest in the non-agriculturalists. The median ratio is highest in I1, followed by I2 and C. This implies that there is a gradient of wear from the anterior dentition with most wear relative to M1 in I1 and least in C. Additionally the medians are slightly lower in the non-agriculturalists than the agriculturalists. To sum up, there is a gradient of variability and degree in the dentine percent ratios along the anterior tooth row with highest values (relative to M1 dentine percent) and greatest variability in I1 and least in C. This trend is strongest in the agriculturalists. This occlusal wear pattern is very similar to that of the full collection (Figures 7.47 - 7.49), but more marked in the inland behavioural groups. Once more this contrasts with the coastal behavioural groups (Figures 7.117 - 7.119).



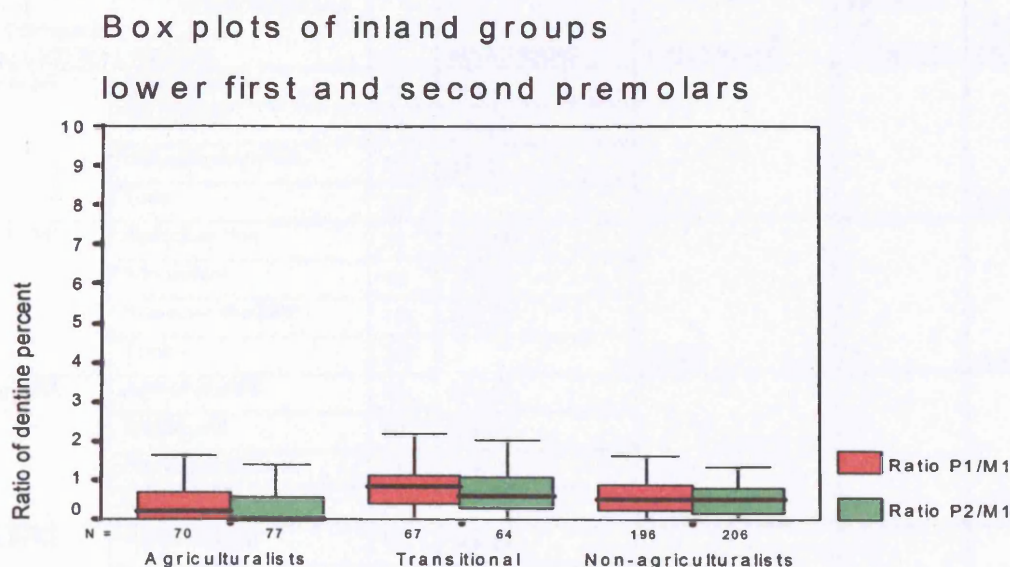


Figure 7.188: Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for the inland behavioural groups. Proportions are shown for the first and second premolars (P1 and P2).

Similar to the full collection (Figure 7.48) the inland behavioural groups (Figure 7.188) show considerable overlap in the interquartile and overall ranges for both P1 and P2 ratios. The transitional group has the highest median and interquartile range and the agriculturalists have the lowest. The differences are however much smaller than the anterior teeth above.

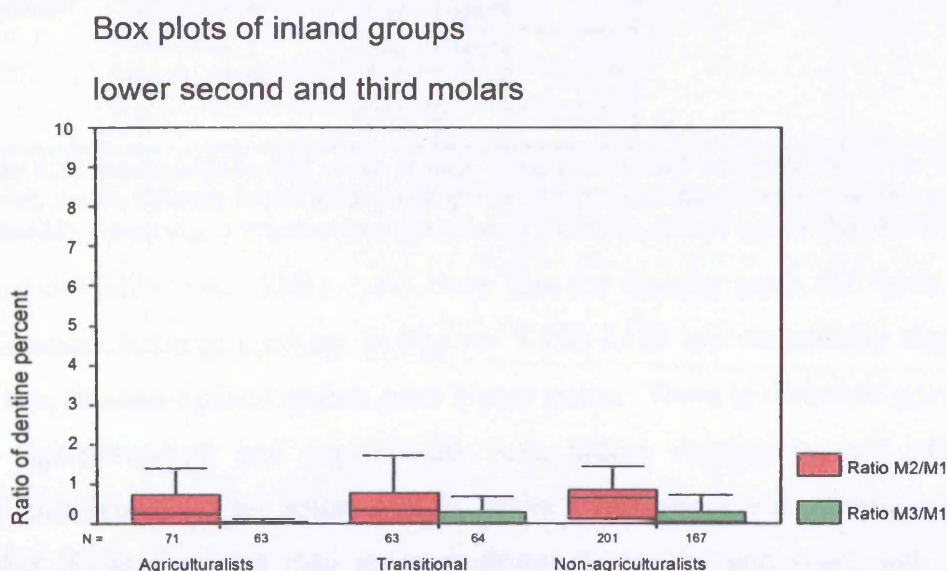


Figure 7.189: Box plots of the dentine percent (DP), expressed as proportion of the first molar dentine percent (DPM1), for the inland behavioural groups. Proportions are shown for second and third molar (M2 and M3).

For M2 and M3 there is less variation between the medians and interquartile ranges than in the anterior teeth. Nonetheless the non-agriculturalists have the highest median value for M2.

INLAND TRANSITIONAL AGRICULTURAL GROUPS		AGRICULTURAL, AND NON-AGRICULTURAL GROUPS	N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Ratio I1/M1	Agriculturalists	46	162.65	63.331	2	0.000	
	Transitional	57	140.60				
	Non-agriculturalists	123	82.56				
	Total	226					
Ratio I2/M1	Agriculturalists	50	178.04	57.887	2	0.000	
	Transitional	59	173.93				
	Non-agriculturalists	156	103.08				
	Total	265					
Ratio C/M1	Agriculturalists	53	199.42	62.724	2	0.000	
	Transitional	62	200.65				
	Non-agriculturalists	184	118.70				
	Total	299					
Ratio P1/M1	Agriculturalists	70	118.29	33.065	2	0.000	
	Transitional	67	212.54				
	Non-agriculturalists	196	168.83				
	Total	333					
Ratio P2/M1	Agriculturalists	77	117.26	36.622	2	0.000	
	Transitional	64	214.15				
	Non-agriculturalists	206	182.74				
	Total	347					
Ratio M2/M1	Agriculturalists	71	141.92	9.737	2	0.008	
	Transitional	63	156.37				
	Non-agriculturalists	201	180.86				
	Total	335					
Ratio M3/M1	Agriculturalists	63	120.59	12.543	2	0.002	
	Transitional	64	140.70				
	Non-agriculturalists	167	160.26				
	Total	294					

Kruskal-Wallis tests (Table 7.36) show that for anterior teeth and both premolars, the differences between medians in Figures 7.187-7.188 are statistically significant. In the molars, the non-agriculturalists have higher ratios. There is therefore good evidence that the agriculturalists and transitionals have higher dentine percent ratios than non-agriculturalists for the anterior teeth, while transitionals and non-agriculturalists have higher dentine percent than the agriculturalists for the premolars and molars. These differences were more marked in the inland behavioural groups than in either the full collection or coastal sections above.

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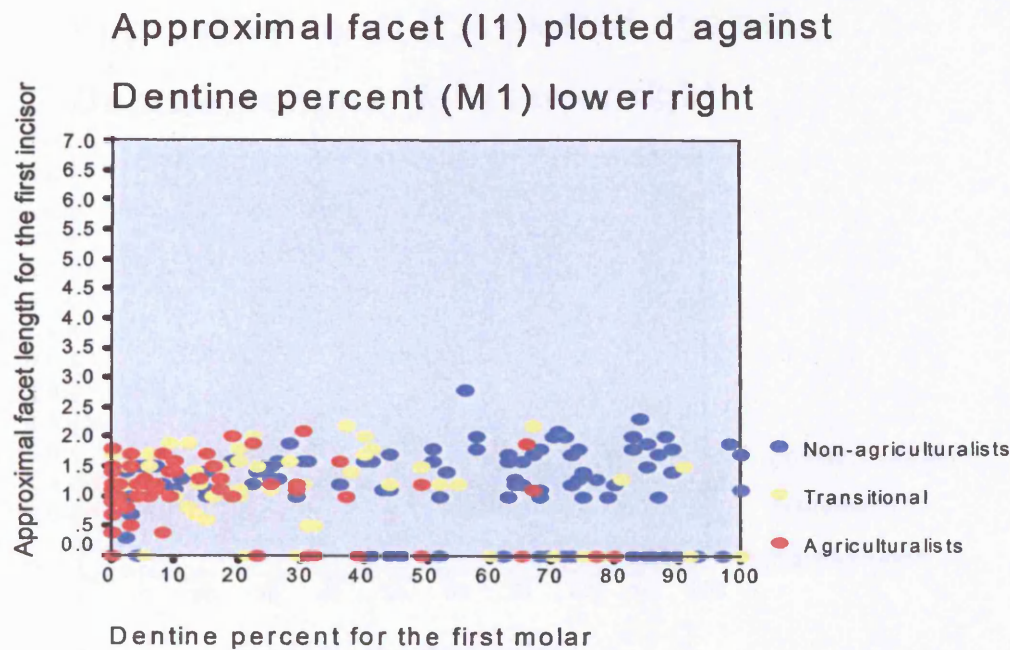


Figure 7.190: Scatter plot of the approximal facet length (mm) of lower right I1 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups.

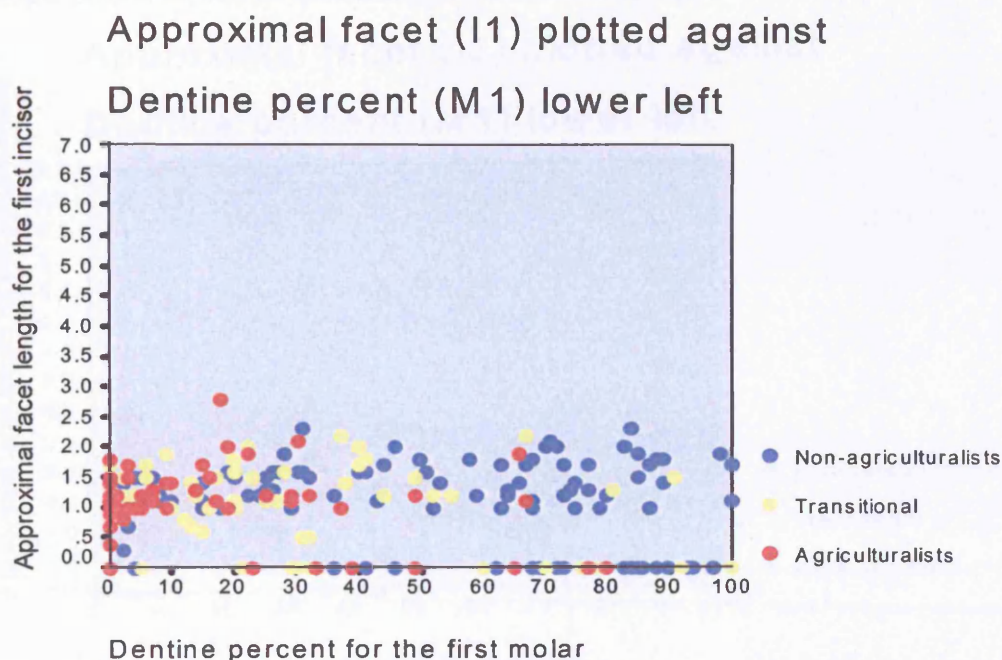


Figure 7.191: Scatter plot of the approximal facet length (mm) of lower left I1 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups.

In plots for I1, (Figures 7.190 and 7.191) the scatters of points for the different inland behavioural groups overlap extensively, but there are some slight variations between them. The scatters are positioned slightly higher for the agriculturalists and transitionals than for the non-agriculturalists. This implies that, for any given M1 occlusal wear score, the I1 approximal facet in these groups tends to be longer. The scatters for I2 and C (Figures 7.192-7.195) overlap more extensively between the inland behavioural groups.

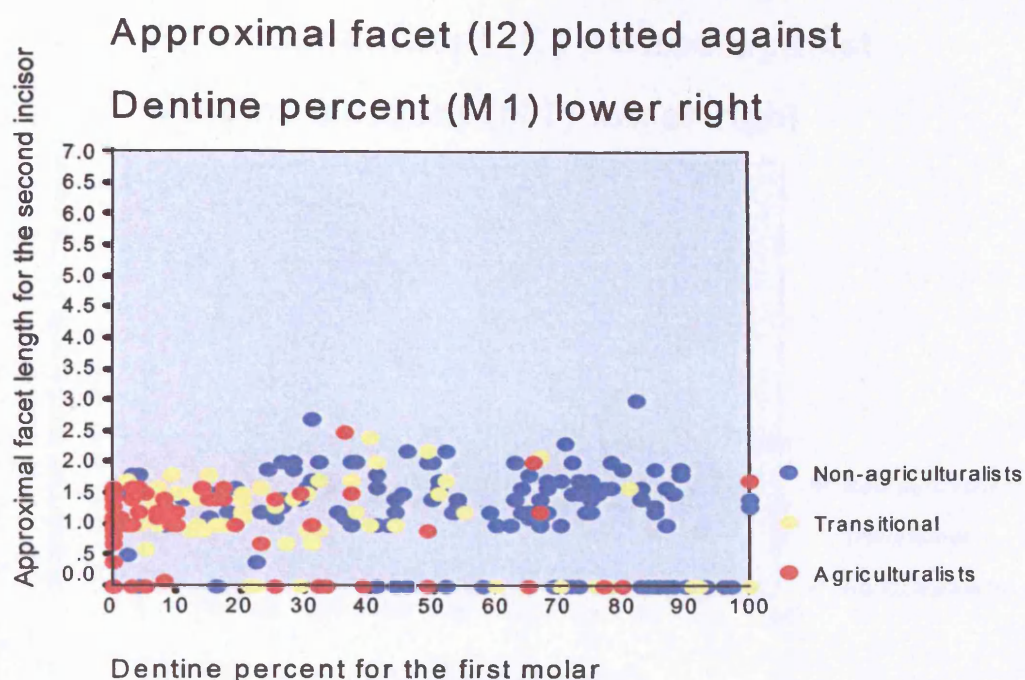


Figure 7.192: Scatter plot of the approximal facet length (mm) of lower right I2 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups.

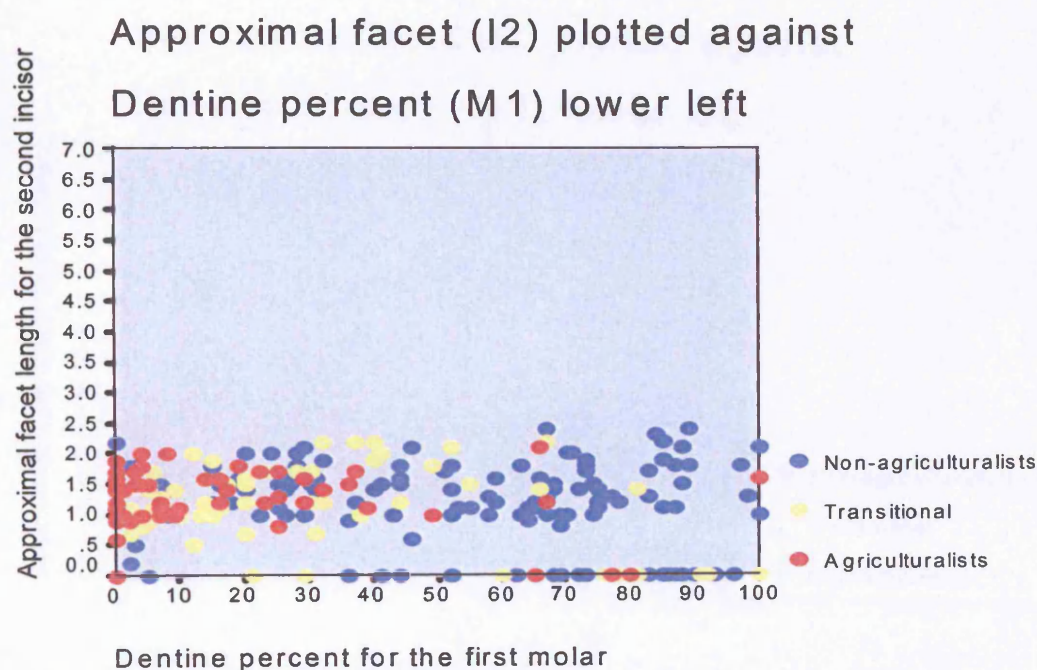


Figure 7.193: Scatter plot of the approximal facet length (mm) of lower left I2 plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups.



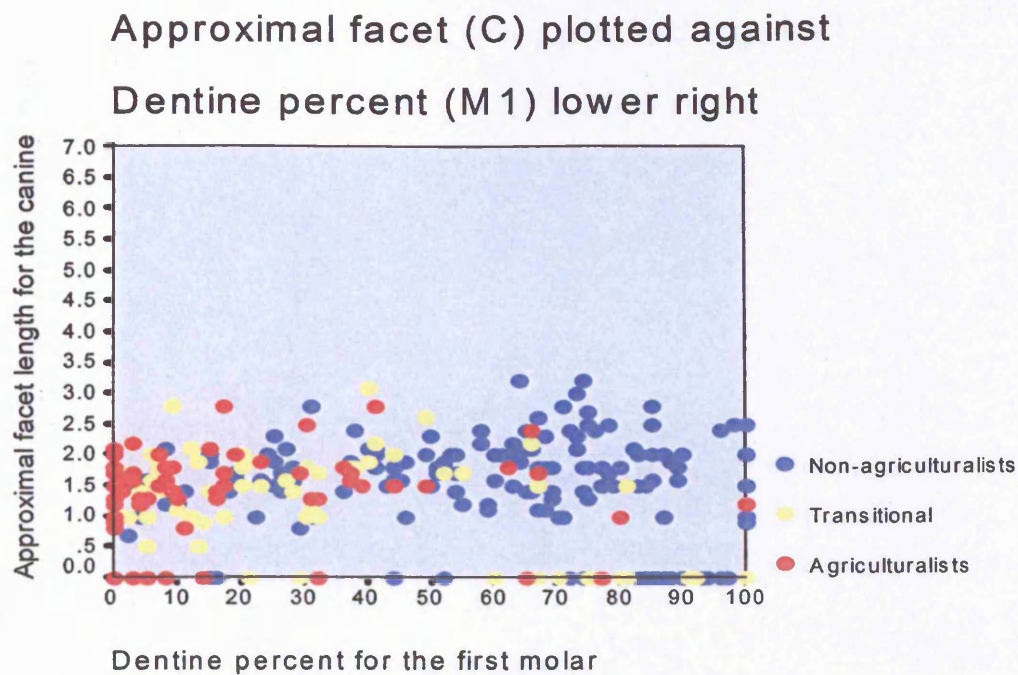


Figure 7.194: Scatter plot of the approximal facet length (mm) of lower right C plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups.

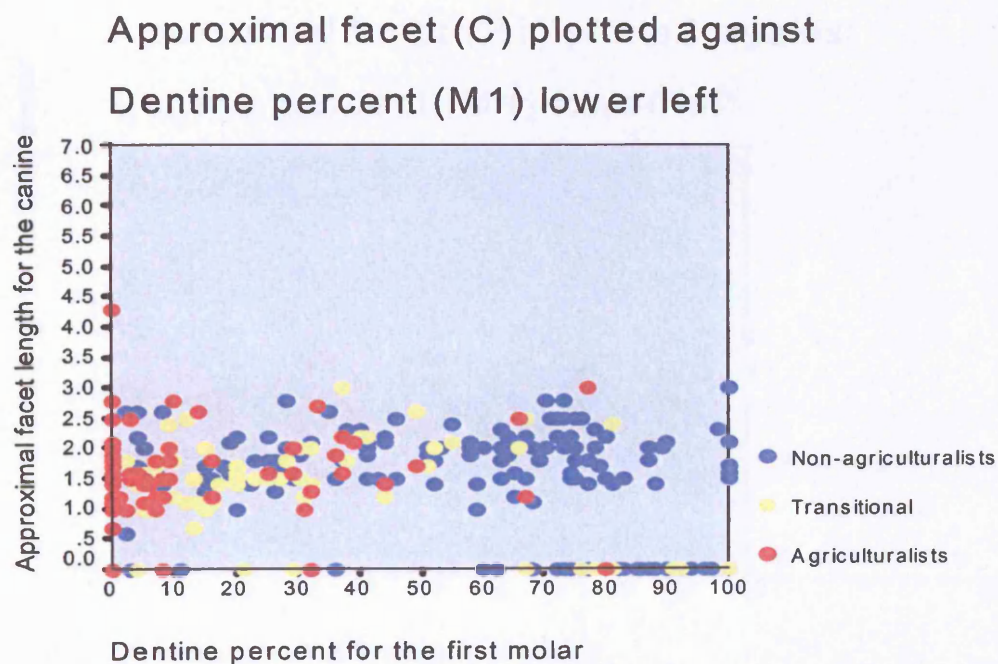


Figure 7.195: Scatter plot of the approximal facet length (mm) of lower left C plotted against occlusal wear (dentine percent for M1) for the different inland behaviour groups.



INLAND AGRICULTURAL, TRANSITIONAL AND NON-AGRICULTURAL GROUPS		N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE	
Approximal percent I1	facet/Dentine	Agriculturalists	55	147.95	16.252	2	0.000
		Transitional	59	142.51			
		Non-agriculturalists	136	109.04			
		Total	250				
Approximal percent I2	facet/Dentine	Agriculturalists	65	162.30	18.325	2	0.000
		Transitional	63	194.47			
		Non-agriculturalists	183	140.52			
		Total	311				
Approximal percent C	facet/Dentine	Agriculturalists	68	195.88	21.108	2	0.000
		Transitional	66	213.18			
		Non-agriculturalists	214	155.78			
		Total	348				
Approximal percent P1	facet/Dentine	Agriculturalists	72	220.29	35.999	2	0.000
		Transitional	67	217.32			
		Non-agriculturalists	217	152.65			
		Total	356				
Approximal percent P2	facet/Dentine	Agriculturalists	69	235.11	57.100	2	0.000
		Transitional	62	214.84			
		Non-agriculturalists	216	142.76			
		Total	347				
Approximal percent M1	facet/Dentine	Agriculturalists	81	264.60	83.144	2	0.000
		Transitional	69	232.47			
		Non-agriculturalists	226	147.80			
		Total	376				
Approximal percent M2	facet/Dentine	Agriculturalists	68	224.43	57.770	2	0.000
		Transitional	63	221.55			
		Non-agriculturalists	211	139.50			
		Total	342				
Approximal percent M3	facet/Dentine	Agriculturalists	53	171.07	52.182	2	0.000
		Transitional	62	197.52			
		Non-agriculturalists	171	115.37			
		Total	286				

Table 7.37: Kruskal-Wallis of the lower right approximal facet length (mm)/dentine percent for the first (I1) and second incisor (I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2, M3) ratios.

**Kruskal-Wallis test lower left**

INLAND AGRICULTURAL, TRANSITIONAL AND NON-AGRICULTURAL GROUPS		N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE	
Approximal percent I1	facet/Dentine	Agriculturalists	51	143.81	14.238	2	0.000
		Transitional	57	145.75			
		Non-agriculturalists	142	110.79			
		Total	250				
Approximal percent I2	facet/Dentine	Agriculturalists	56	171.82	26.442	2	0.000
		Transitional	59	172.74			
		Non-agriculturalists	169	122.23			
		Total	284				
Approximal percent C	facet/Dentine	Agriculturalists	56	191.61	33.796	2	0.000
		Transitional	64	197.01			
		Non-agriculturalists	194	134.62			
		Total	314				
Approximal percent P1	facet/Dentine	Agriculturalists	58	224.16	56.599	2	0.000
		Transitional	67	212.90			
		Non-agriculturalists	209	137.22			
		Total	334				
Approximal percent P2	facet/Dentine	Agriculturalists	62	228.27	68.836	2	0.000
		Transitional	62	227.81			
		Non-agriculturalists	215	136.53			
		Total	339				
Approximal percent M1	facet/Dentine	Agriculturalists	47	215.56	66.977	2	0.000
		Transitional	65	213.48			
		Non-agriculturalists	203	126.91			
		Total	315				
Approximal percent M2	facet/Dentine	Agriculturalists	49	210.95	57.278	2	0.000
		Transitional	64	191.78			
		Non-agriculturalists	189	122.45			
		Total	302				
Approximal percent M3	facet/Dentine	Agriculturalists	39	164.76	49.563	2	0.000
		Transitional	60	166.73			
		Non-agriculturalists	152	99.98			
		Total	251				

Table 7.38: Kruskal-Wallis of the lower left approximal facet length (mm)/dentine percent for the first (I1) and second incisor (I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2, M3) ratios.

The Kruskal-Wallis tests (Tables 7.37 and 7.38) show that, even though these differences are small they are still statistically significant.

To summarise the inland behavioural groups show a very similar pattern of differences in approximal wear to the full collection (Figures 7.50-7.71).

### Occlusal angle measurement

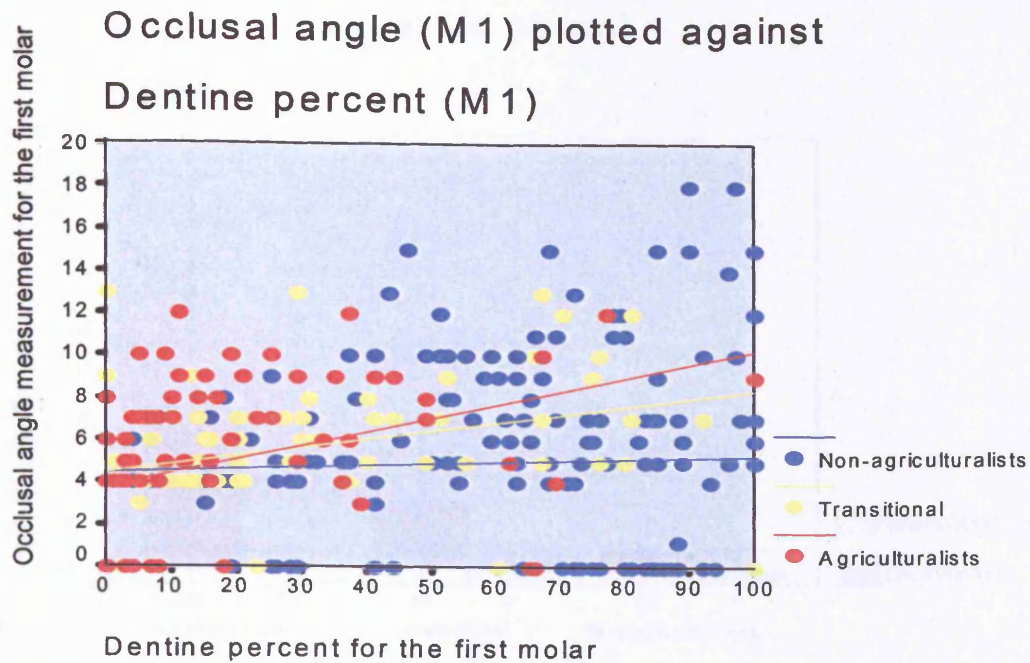


Figure 7.212: Scatter plot of the M1 occlusal angle plotted against M1 occlusal wear (dentine percent), for different inland behavioural groups.

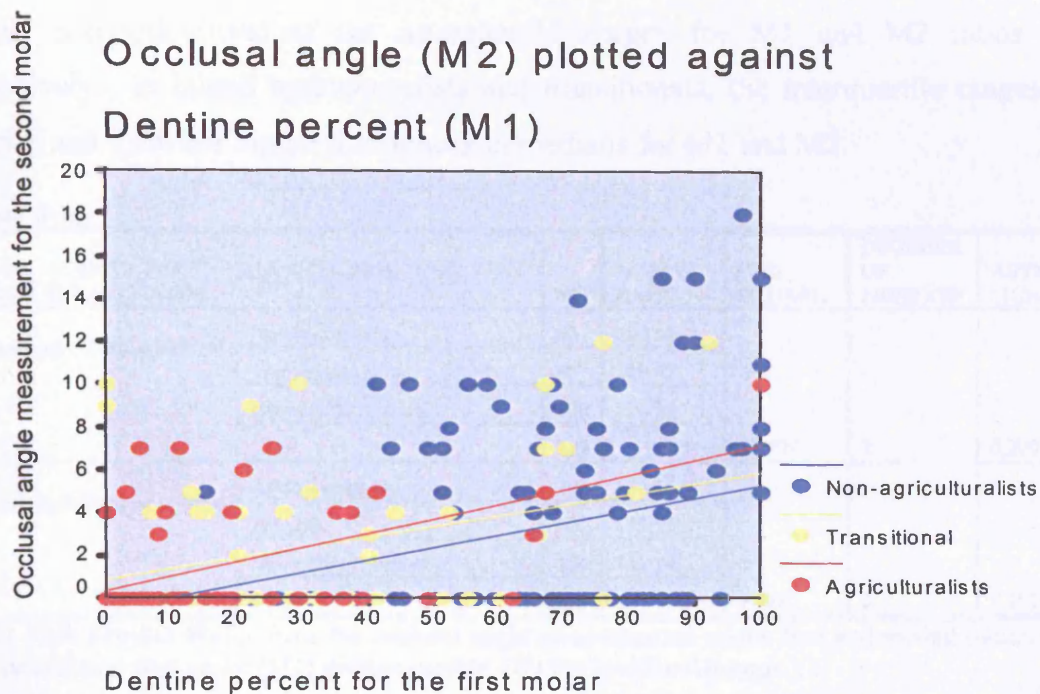


Figure 7.213: Scatter plot of the M2 occlusal angle plotted against M1 occlusal wear (dentine percent), for different inland behavioural groups.

The scatter plots of M1 and M2 occlusal angle measurement plotted against M1 dentine percent (Figures 7.212 and 7.213) show overlap of the scatters, but with some variation between the inland collections. In general, the angle increases with occlusal wear. The inland agricultural scatters rise more steeply than the transitionals and non-agriculturalists in both graphs.



## Kruskal-Wallis test

	SEX	N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Ratio I1/M1	female	81	94.72	0.672	2	0.715
	male	93	88.37			
	unknown	8	95.25			
	Total	182				
Ratio I2/M1	female	81	95.14	1.576	2	0.455
	male	93	90.03			
	unknown	8	71.81			
	Total	182				
Ratio C/M1	female	81	89.51	1.285	2	0.526
	male	93	94.69			
	unknown	8	74.56			
	Total	182				
Ratio P1/M1	female	126	140.54	5.979	2	0.055
	male	163	165.06			
	unknown	17	138.65			
	Total	306				
Ratio P2/M1	female	126	147.29	3.302	2	0.192
	male	163	161.03			
	unknown	17	127.32			
	Total	306				
Ratio M2/M1	female	110	129.15	0.194	2	0.907
	male	142	133.05			
	unknown	10	135.45			
	Total	262				
Ratio M3/M1	female	110	115.01	11.475	2	0.003
	male	142	141.89			
	unknown	10	165.35			
	Total	262				

Table 7.40: Kruskal-Wallis from the first and second incisors (I1 and I2), and canine (C) first and second premolars (P1 and P2) second and third molars (M2, and M3) ratios (over first molar (M1) dentine percent) of the males, females and unknown sex individuals for the inland groups.

The Kruskal-Wallis test (Table 7.40) confirms that there are no significant differences in median ratios for anterior teeth, premolars or M2 ratios. In M3 the median ratio is significant but small.

## Kruskal-Wallis lower right

	SEX	N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/Dentine percent I1	female	110	128.68	4.490	2	0.106
	male	127	119.12			
	unknown	13	160.88			
	Total	250				
Approximal facet/Dentine percent I2	female	134	162.40	1.639	2	0.441
	male	159	149.81			
	unknown	18	163.08			
	Total	311				
Approximal facet/Dentine percent C	female	155	178.79	0.846	2	0.655
	male	174	172.37			
	unknown	19	159.00			
	Total	348				
Approximal facet/Dentine percent P1	female	157	178.97	8.722	2	0.301
	male	179	174.40			
	unknown	20	211.50			
	Total	356				
Approximal facet/Dentine percent P2	female	146	176.17	8.772	2	0.012
	male	178	164.96			
	unknown	23	230.20			
	Total	347				
Approximal facet/Dentine percent M1	female	158	195.44	16.198	2	0.000
	male	191	172.75			
	unknown	27	259.30			
	Total	376				
Approximal facet/Dentine percent M2	female	146	176.10	7.758	2	0.021
	male	171	160.83			
	unknown	25	217.64			
	Total	342				
Approximal facet/Dentine percent M3	female	120	140.64	0.399	2	0.819
	male	152	146.33			
	unknown	14	137.36			
	Total	286				

Table 7.41: Kruskal-Wallis test of the approximal wear (AP), expressed as proportion of the first molar dentine percent (DPM1), for the different sex groups. Proportions are shown for the lower right first and second incisors (I1 and I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2 and M3).

**Kruskal-Wallis lower left**

	SEX	N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/Dentine percent I1	female	109	129.76	2.691	2	0.260
	male	128	119.53			
	unknown	13	148.58			
	Total	250				
Approximal facet/Dentine percent I2	female	118	141.46	11.615	2	0.003
	male	151	136.53			
	unknown	15	210.77			
	Total	284				
Approximal facet/Dentine percent C	female	137	161.92	1.219	2	0.544
	male	162	152.48			
	unknown	15	171.33			
	Total	314				
Approximal facet/Dentine percent P1	female	139	176.28	3.019	2	0.221
	male	175	158.92			
	unknown	20	181.53			
	Total	334				
Approximal facet/Dentine percent P2	female	143	175.40	3.342	2	0.188
	male	175	162.17			
	unknown	21	198.52			
	Total	339				
Approximal facet/Dentine percent M1	female	127	163.26	7.907	2	0.019
	male	168	148.32			
	unknown	20	205.93			
	Total	315				
Approximal facet/Dentine percent M2	female	124	157.15	8.836	2	0.012
	male	156	140.63			
	unknown	22	196.70			
	Total	302				
Approximal facet/Dentine percent M3	female	109	130.04	0.774	2	0.679
	male	131	123.65			
	unknown	11	114.05			
	Total	251				

Table 7.42: Kruskal-Wallis test of the approximal wear (AP), expressed as proportion of the first molar dentine percent (DPM1), for the different sex groups. Proportions are shown for the lower left first and second incisors (I1 and I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2 and M3).

The Kruskal-Wallis tests (Tables 7.41 and 7.42) show that, for almost all teeth, the median ratios are not significantly different between males and females. There are higher ratios in the females, but these differences are very small, and vary between left and right.

### Occlusal angle measurement



## Kruskal-Wallis tests

	NON-AGRICULTURALISTS	N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Ratio I1/M1	Kebara	2	153.25	24.415	5	0.000
	El Wad	17	75.65			
	Santa Barbara	21	121.69			
	Indian Knoll	79	77.32			
	Chiggerville	11	85.18			
	Carlston Annis	33	65.85			
	Total	163				
Ratio I2/M1	Kebara	2	186.50	31.692	5	0.000
	El Wad	19	98.84			
	Santa Barbara	26	156.29			
	Indian Knoll	94	88.49			
	Chiggerville	16	99.94			
	Carlston Annis	46	97.27			
	Total	203				
Ratio C/M1	Kebara	2	143.75	19.880	5	0.001
	El Wad	24	133.46			
	Santa Barbara	27	161.35			
	Indian Knoll	109	114.40			
	Chiggerville	20	133.60			
	Carlston Annis	55	94.81			
	Total	237				
Ratio P1/M1	Kebara	2	12.50	6.149	5	0.292
	El Wad	22	113.27			
	Santa Barbara	28	126.91			
	Indian Knoll	116	127.59			
	Chiggerville	21	134.33			
	Carlston Annis	59	121.75			
	Total	248				
Ratio P2/M1	Kebara	3	91.00	5.151	5	0.398
	El Wad	26	112.77			
	Santa Barbara	28	151.84			
	Indian Knoll	122	129.59			
	Chiggerville	22	144.11			
	Carlston Annis	62	133.54			
	Total	263				
Ratio M2/M1	Kebara	3	63.17	6.469	5	0.263
	El Wad	31	110.60			
	Santa Barbara	27	122.06			
	Indian Knoll	117	136.33			
	Chiggerville	23	142.67			
	Carlston Annis	61	136.19			
	Total	262				

Approximal facet/Dentine percent P1	Kebara	2	255.50	13.351	5	0.020
	El Wad	22	169.27			
	Santa Barbara	29	112.16			
	Indian Knoll	125	139.38			
	Chiggerville	23	127.80			
	Carlston Annis	69	126.61			
	Total	270				
Approximal facet/Dentine percent P2	Kebara	3	249.67	17.241	5	0.004
	El Wad	27	174.98			
	Santa Barbara	29	108.45			
	Indian Knoll	128	139.31			
	Chiggerville	22	119.95			
	Carlston Annis	66	134.25			
	Total	275				
Approximal facet/Dentine percent M1	Kebara	3	256.67	13.300	5	0.021
	El Wad	32	177.83			
	Santa Barbara	30	150.88			
	Indian Knoll	131	143.87			
	Chiggerville	23	118.35			
	Carlston Annis	72	137.92			
	Total	291				
Approximal facet/Dentine percent M2	Kebara	3	250.00	13.828	5	0.017
	El Wad	31	169.65			
	Santa Barbara	30	119.42			
	Indian Knoll	124	138.27			
	Chiggerville	24	123.35			
	Carlston Annis	63	131.00			
	Total	275				
Approximal facet/Dentine percent M3	Kebara	3	203.33	17.148	5	0.004
	El Wad	27	139.11			
	Santa Barbara	13	89.46			
	Indian Knoll	109	103.73			
	Chiggerville	22	93.11			
	Carlston Annis	40	103.03			
	Total	214				

Table 7.45: Kruskal-Wallis of the lower right approximal facet length (mm)/dentine percent for the first (I1) and second incisor (I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2, M3) ratios.

Kruskal-Wallis lower left

NON-AGRICULTURALISTS		N	MEAN RANK	CHI SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/Dentine percent I1	Kebara	3	165.67	13.001	5	0.002
	El Wad	14	114.39			
	Santa Barbara	20	90.80			
	Indian Knoll	90	87.69			
	Chiggerville	15	97.67			
	Carlston Annis	37	76.72			
	Total	179				

Approximal facet/Dentine percent I2	Kebara	3	207.67	17.680	5	0.003
	El Wad	22	149.30			
	Santa Barbara	32	93.41			
	Indian Knoll	102	113.51			
	Chiggerville	20	111.40			
	Carlston Annis	47	105.29			
	Total	226				
Approximal facet/Dentine percent C	Kebara	3	245.50	18.656	5	0.002
	El Wad	20	158.25			
	Santa Barbara	44	103.16			
	Indian Knoll	116	137.33			
	Chiggerville	22	116.89			
	Carlston Annis	56	129.45			
	Total	261				
Approximal facet/Dentine percent P1	Kebara	2	245.50	15.860	5	0.007
	El Wad	23	173.33			
	Santa Barbara	37	108.46			
	Indian Knoll	126	137.38			
	Chiggerville	24	118.40			
	Carlston Annis	59	139.22			
	Total	271				
Approximal facet/Dentine percent P2	Kebara	2	247.50	19.963	5	0.001
	El Wad	24	181.73			
	Santa Barbara	35	98.66			
	Indian Knoll	131	140.92			
	Chiggerville	22	133.75			
	Carlston Annis	62	137.32			
	Total	276				
Approximal facet/Dentine percent M1	Kebara	2	221.50	10.865	5	0.050
	El Wad	23	158.78			
	Santa Barbara	25	120.38			
	Indian Knoll	121	123.96			
	Chiggerville	21	115.19			
	Carlston Annis	61	124.73			
	Total	253				
Approximal facet/Dentine percent M2	Kebara	2	215.50	10.345	5	0.045
	El Wad	26	150.02			
	Santa Barbara	28	104.25			
	Indian Knoll	117	121.00			
	Chiggerville	20	123.80			
	Carlston Annis	52	120.21			
	Total	245				



Kruskal-Wallis test lower right

	SEX	N	MEAN RANK	CHI SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/Dentine percent I1	female	67	87.81	13.452	2	0.001
	male	97	85.06			
	unknown	16	134.72			
	Total	180				
Approximal facet/Dentine percent I2	female	92	121.37	7.556	2	0.023
	male	127	113.82			
	unknown	21	157.10			
	Total	240				
Approximal facet/Dentine percent C	female	107	138.95	0.386	2	0.824
	male	143	133.86			
	unknown	22	141.73			
	Total	272				
Approximal facet/Dentine percent P1	female	105	129.40	2.138	2	0.343
	male	142	136.92			
	unknown	23	154.57			
	Total	270				
Approximal facet/Dentine percent P2	female	103	133.96	3.203	2	0.202
	male	148	136.37			
	unknown	24	165.38			
	Total	275				
Approximal facet/Dentine percent M1	female	109	146.84	24.513	2	0.000
	male	156	132.99			
	unknown	26	220.54			
	Total	291				
Approximal facet/Dentine percent M2	female	104	138.53	24.933	2	0.000
	male	146	125.13			
	unknown	25	210.98			
	Total	275				
Approximal facet/Dentine percent M3	female	83	106.76	0.057	2	0.972
	male	119	108.30			
	unknown	12	104.67			
	Total	214				

Table 7.49: Kruskal-Wallis of the lower right approximal facet length (mm)/dentine percent for the first (I1) and second incisor (I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2, M3) ratios.

**Kruskal-Wallis test lower left**

	SEX	N	MEAN RANK	CHI SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/Dentine percent I1	female	66	87.35	10.762	2	0.005
	male	100	86.01			
	unknown	13	134.19			
	Total	179				
Approximal facet/Dentine percent I2	female	82	109.32	10.077	2	0.006
	male	121	108.78			
	unknown	23	153.24			
	Total	226				
Approximal facet/Dentine percent C	female	99	135.75	1.997	2	0.368
	male	138	125.39			
	unknown	24	143.67			
	Total	261				
Approximal facet/Dentine percent P1	female	99	136.32	3.487	2	0.175
	male	146	131.23			
	unknown	26	161.56			
	Total	271				
Approximal facet/Dentine percent P2	female	105	140.63	1.394	2	0.498
	male	148	134.50			
	unknown	23	154.54			
	Total	276				
Approximal facet/Dentine percent M1	female	92	133.10	15.420	2	0.000
	male	139	114.89			
	unknown	22	177.98			
	Total	253				
Approximal facet/Dentine percent M2	female	92	124.70	14.114	2	0.001
	male	130	112.96			
	unknown	23	172.93			
	Total	245				
Approximal facet/Dentine percent M3	female	78	103.01	2.076	2	0.354
	male	107	93.03			
	unknown	10	112.15			
	Total	195				

Table 7.50: Kruskal-Wallis of the lower left approximal facet length (mm)/dentine percent for the first (I1) and second incisor (I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2, M3) ratios.

The Kruskal-Wallis test (Tables 7.49-7.50) shows a number of the comparison are statistically significant but does not show a strong difference between the males and females. Rather the statistical difference is between the known sex and unknown sex groups.

### **Occlusal angle of the males, females and unknown sex for the non-agriculturalists**

Approximal facet/Dentine percent P1	Levantine NA	24	176.46	7.526	1	0.006
	N. America NA	246	131.50			
	Total	270				
Approximal facet/Dentine percent P2	Levantine NA	30	182.45	10.624	1	0.001
	N. America NA	245	132.56			
	Total	275				
Approximal facet/Dentine percent M1	Levantine NA	35	184.59	8.494	1	0.004
	N. America NA	256	140.72			
	Total	291				
Approximal facet/Dentine percent M2	Levantine NA	34	176.74	9.222	1	0.002
	N. America NA	241	132.54			
	Total	275				
Approximal facet/Dentine percent M3	Levantine NA	30	145.53	13.180	1	0.000
	N. America NA	184	101.30			
	Total	214				

Table 7.53: Kruskal-Wallis of the lower right approximal facet length (mm)/dentine percent for the first (I1) and second incisor (I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2, M3) ratios.

**Kruskal-Wallis test lower left**

LIFEWAYS BY AREA		N	MEAN RANK	CHI SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/Dentine percent I1	Levantine NA	17	123.44	8.237	1	0.004
	N. America NA	162	86.49			
	Total	179				
Approximal facet/Dentine percent I2	Levantine NA	25	156.30	12.828	1	0.000
	N. America NA	201	108.18			
	Total	226				
Approximal facet/Dentine percent C	Levantine NA	23	169.63	7.206	1	0.007
	N. America NA	238	127.27			
	Total	261				
Approximal facet/Dentine percent P1	Levantine NA	25	179.10	8.783	1	0.003
	N. America NA	246	131.62			
	Total	271				
Approximal facet/Dentine percent P2	Levantine NA	26	186.79	10.645	1	0.001
	N. America NA	250	133.48			
	Total	276				
Approximal facet/Dentine percent M1	Levantine NA	25	163.80	7.154	1	0.007
	N. America NA	228	122.96			
	Total	253				
Approximal facet/Dentine percent M2	Levantine NA	28	154.70	6.339	1	0.012
	N. America NA	217	118.91			
	Total	245				
Approximal facet/Dentine percent M3	Levantine NA	29	120.62	5.482	1	0.019
	N. America NA	166	94.05			
	Total	195				

Table 7.54: Kruskal-Wallis of the lower left approximal facet length (mm)/dentine percent for the first (I1) and second incisor (I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2, M3) ratios.

percent P1	coastal	53	141.27			
	Total	270				
Approximal facet/Dentine percent P2	inland	216	135.79	0.782	1	0.376
	coastal	59	146.08			
	Total	275				
Approximal facet/Dentine percent M1	inland	226	139.38	6.366	1	0.012
	coastal	65	169.03			
	Total	291				
Approximal facet/Dentine percent M2	inland	211	134.40	1.861	1	0.173
	coastal	64	149.87			
	Total	275				
Approximal facet/Dentine percent M3	inland	171	102.20	6.245	1	0.012
	coastal	43	128.58			
	Total	214				

Table 7.57: Kruskal-Wallis of the lower right approximal facet length (mm)/dentine percent for the first (I1) and second incisor (I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2, M3) ratios.

**Kruskal-Wallis test lower left**

NON-AGRICULTURALISTS INLAND AND COASTAL		N	MEAN RANK	CHI SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/Dentine percent I1	inland	142	85.88	4.564	1	0.033
	coastal	37	105.80			
	Total	179				
Approximal facet/Dentine percent I2	inland	169	110.97	1.066	1	0.302
	coastal	57	120.99			
	Total	226				
Approximal facet/Dentine percent C	inland	194	132.73	0.435	1	0.509
	coastal	67	125.98			
	Total	261				
Approximal facet/Dentine percent P1	inland	209	135.72	0.012	1	.912
	coastal	62	136.94			
	Total	271				
Approximal facet/Dentine percent P2	inland	215	139.15	0.065	1	0.799
	coastal	61	136.22			
	Total	276				
Approximal facet/Dentine percent M1	inland	203	123.28	2.702	1	0.100
	coastal	50	142.09			
	Total	253				
Approximal facet/Dentine percent M2	inland	189	121.08	0.607	1	0.436
	coastal	56	129.47			
	Total	245				
Approximal facet/Dentine percent M3	inland	152	95.92	0.937	1	0.333
	coastal	43	105.35			
	Total	195				

Table 7.58: Kruskal-Wallis of the lower left approximal facet length (mm)/dentine percent for the first (I1) and second incisor (I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2, M3) ratios.

**Occlusal angle measurement**



**Kruskal-Wallis test lower right**

	SEX	N	MEAN RANK	CHI SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/Dentine percent I1	female	39	44.49	0.862	2	0.650
	male	37	41.76			
	unknown	8	36.25			
	Total	84				
Approximal facet/Dentine percent I2	female	44	60.31	4.988	2	0.083
	male	48	48.44			
	unknown	13	45.12			
	Total	105				
Approximal facet/Dentine percent C	female	52	63.46	3.559	2	0.169
	male	52	56.70			
	unknown	12	44.79			
	Total	116				
Approximal facet/Dentine percent P1	female	50	64.26	6.215	2	0.045
	male	48	49.91			
	unknown	13	46.73			
	Total	111				
Approximal facet/Dentine percent P2	female	50	66.65	2.564	2	0.277
	male	57	56.96			
	unknown	17	68.85			
	Total	124				
Approximal facet/Dentine percent M1	female	57	72.30	1.908	2	0.385
	male	56	62.66			
	unknown	20	64.05			
	Total	133				
Approximal facet/Dentine percent M2	female	51	62.24	1.574	2	0.455
	male	47	57.30			
	unknown	18	51.06			
	Total	116				
Approximal facet/Dentine percent M3	female	41	50.11	0.169	2	0.919
	male	46	49.98			
	unknown	13	53.58			
	Total	100				

Table 7.65: Kruskal-Wallis of the lower right approximal facet length (mm)/dentine percent for the first (I1) and second incisor (I2), canine (C), first and second premolars (P1 and P2), first, second and third molars (M1, M2, M3) ratios.

**Kruskal-Wallis test lower left**

	SEX	N	MEAN RANK	CHI SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Approximal facet/Dentine percent I1	female	38	42.01	1.027	2	0.598
	male	32	37.56			
	unknown	8	35.31			
	Total	78				
Approximal facet/Dentine percent I2	female	43	46.21	3.921	2	0.141
	male	42	45.30			
	unknown	9	63.94			
	Total	94				

**Kruskal-Wallis test**

	SEX	N	MEAN RANK	CHI SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Occlusal angle/Dentine percent M1	female	49	64.64	10.798	2	0.005
	male	58	50.01			
	unknown	10	83.50			
	Total	117				
Occlusal angle/Dentine percent M2	female	45	52.87	22.007	2	0.000
	male	57	51.39			
	unknown	7	98.07			
	Total	109				

Table 7.67 Kruskal-Wallis occlusal angle (degrees) ratio of the first and second molar (M1 and M2) ratios (over dentine percent M1) agriculturalists.

The comparison of the sex groups for the agriculturalists shows little difference between the occlusal wear, approximal wear or occlusal angle.

**Summary**

1. The agricultural groups show only slight differences in the occlusal wear patterns, with Hawikuh and Shannon having more occlusal wear for each stage of M1 occlusal wear in the anterior teeth than Florida and Abu Hureyra. In the premolars and molars the opposite is the case.
2. For approximal wear, the premolars and molars showed Hawikuh and Shannon had higher median facet lengths relative to M1 occlusal wear than Abu Hureyra and Florida. There was less difference between the collections in the anterior teeth.
3. In the occlusal angle, Florida generally had the lowest median values.
4. There were no consistent difference between males and females within the agriculturalists group.

**Kruskal-Wallis test**

LIFEWAYS BY AREA		N	MEAN RANK	CHI SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Occlusal angle/Dentine percent M1	Levant A	15	82.70	9.048	1	0.003
	N. American A	101	54.91			
	Total	116				
Occlusal angle/Dentine percent M2	Levant A	9	100.56	34.058	1	0.000
	N. American A	99	50.31			
	Total	108				

Table 7.71: Kruskal-Wallis occlusal angle (degrees) ratio of the first and second molar (M1 and M2) ratios (over dentine percent M1).

**Summary:**

1. There was little difference in the pattern of occlusal wear (relative to M1 occlusal wear) between the Levantine and North American assemblages.
2. The approximal facet showed the Levantine and North American groups had similar approximal wear for any given stage of M1 occlusal wear.
3. The Levantine group had larger occlusal surface angles relative to the M1 occlusal wear than the North American group.

**Kruskal-Wallis test**

AGRICULTURE COASTAL TO INLAND		N	MEAN RANK	CHI-SQUARE	DEGREES OF FREEDOM	ASYMPTOTIC SIGNIFICANCE
Occlusal angle/Dentine percent M1	Coastal group	48	47.85	8.323	1	0.004
	Inland group	68	66.01			
	Total	116				
Occlusal angle/Dentine percent M2	Coastal group	36	60.07	2.739	1	0.098
	Inland group	72	51.72			
	Total	108				

Table 7.75: Kruskal-Wallis occlusal angle (degrees) ratio of the first and second molar (M1 and M2) ratios (over dentine percent M1) for the inland and coastal non-agriculturalists.

**Summary:**

1. For the anterior teeth the inland group showed more advanced occlusal wear relative to M1 occlusal wear than the coastal group. By contrast, for the cheek teeth, the coastal group showed more advanced occlusal wear relative to M1 occlusal wear than the inland group.
2. The approximal wear pattern was similar in the inland and coastal groups.
3. The coastal group had more strongly angled occlusal surfaces relative to M1 occlusal wear than the inland group in M1 only.



## Chapter 8 — Discussion

As earlier established (chapter 4), this project was designed to test the effects of adoption of agriculture on tooth wear. The goals of chapter 8 are to:

- review the hypothesis in the light of the results
- consider the limitations of the project and explore ways to address them.

### 8.1 Hypothesis review

The hypothesis developed in chapter 4 stated that, relative to agriculturalists, non-agriculturalists should have:

- a high occlusal attrition rate, with reference to independent age-at-death estimates (pubic symphysis and auricular surface morphology)
- a strong gradient of occlusal attrition, with the lowest rates on the more posterior teeth (P2, P1, M2 and M3) and highest in the more anterior teeth (I1, I2, C and P1)
- more approximal attrition wear for any given occlusal wear stage
- a smaller change in the occlusal wear plane angle of the molars per stage of occlusal attrition.

It is assumed that transitionals would occupy an intermediate position between non-agriculturalists and agriculturalists.

#### ***High occlusal wear rate relative to independent age indicators***

Section 7.1 in chapter 7 showed that the median values for occlusal attrition, expressed as the relative exposure of dentine on the occlusal surface, increases with independently determined age. This was true in teeth selected from all parts of the dentition, although M1 and I1 always had higher values for attrition than P1. This trend of increasing occlusal attrition with age was most marked in the non-agriculturalists, least in the agriculturalists and the transitionals were in between. Approximal wear facet lengths increase slightly with age in the youngest three independently determined age groups but decrease markedly in the oldest age group. Once again, this age trend was most marked in the non-agriculturalists, least marked in the agriculturalists and the transitionals were between the two. This agrees with the findings of Hinton (1982) and supports the hypothesis in chapter 4.

Although there were clear trends in the median values for occlusal attrition, the interquartile ranges for different behavioural groups overlap. In addition the interquartile

decrease, but this pattern is less marked in P1 and even less so in I1. Therefore it is difficult to determine if the approximal wear actually increases with the increase of occlusal wear.

***Relative to agriculturalists, non-agriculturalists have a smaller change in the occlusal wear plane angle of the molars per stage of occlusal wear***

Box plots in chapter 7, section 7.2 showed that the median values for occlusal wear plane angles expressed as a proportion to M1 occlusal wear. In the full collection (section 7.2.A), the agriculturalists and transitionals showed a larger difference between median ratios for M1 and M2, but the transitionals had a slightly higher median value than the agriculturalists, which in turn was higher than the non-agriculturalists for M1. In general, occlusal angle increases with occlusal wear, but the transitional group showed a steeper angle increase than the agriculturalists and non-agriculturalists. Smith's (1984) results were limited to the occlusal surface angles of M1, but the more extensive results in the present research showed that the non-agriculturalists had smaller occlusal wear angle (relative to M1 occlusal wear) than the transitionals and agriculturalists. The hypothesis defined in chapter 4 is more strongly supported in M2 than in M1.

***Summary:***

To sum up, only two of the four hypotheses were supported; the high occlusal wear rate in non-agriculturalists relative to independent age indicators and the agriculturalists and transitionals showed a higher rate of change of occlusal wear plane angles per stage of M1 molar occlusal wear. Gradients of occlusal and approximal wear did exist in the dentition, but this seemed to be strongly related to the eruption sequence and size of the teeth in the material studied, the agriculturalists and transitionals showed a stronger gradient than the non-agriculturalists. These conclusions however were drawn from the full collection and it is necessary to find if they are consistent in the different sub-groups (coastal, inland, regions, and sexes).

## **8.2 Further investigation of the hypothesis**

***Coastal non-agriculturalists compared to coastal agriculturalists***

Chapter 7, section 7.2.B showed that there was little difference between the coastal non-agriculturalists and agriculturalists occlusal attrition patterns and approximal facet lengths (relative to M1 occlusal wear). Once again these findings do not support the hypothesis outlined above. The hypothesis is also not supported by occlusal surface wear plane angles. Coastal non-agriculturalists had larger molar occlusal wear facet angles for any given stage of M1 occlusal wear than the coastal agriculturalists. This is the opposite of what was found in the full collection (section 7.2 A). It is possible that the adoption of

agriculture did not have as large of impact on the diet and behaviour of coastal groups. Finds of fish hooks, nets and weights remained common on agricultural sites, so they clearly continued to fish and gather resources from the coast (Table 8.2). Stable isotope work has not been done on this site (Florida), but it would be interesting to investigate the extent to which maize agriculture was incorporated into the diet.

### ***Inland non-agriculturalists compared to transitionals and agriculturalists***

There were clearer differences between inland behavioural groups section 7.2.C. Inland non-agriculturalists had less occlusal wear (relative to M1 occlusal wear) than the transitionals and agriculturalists. These gradients were particularly marked in the anterior teeth. The inland non-agriculturalists also had smaller approximal wear facets (relative to M1 occlusal wear) than the agriculturalists and transitionals. This trend however was more marked in the molars and least in the anterior teeth. These results argue even more strongly against the hypothesis outlined above and the results of the full collection. On the other hand, the inland non-agriculturalists had smaller occlusal wear plane angles (relative to M1 occlusal wear) than the agriculturalists and transitionals. The difference however is not as marked as it is in the coastal collections. The adoption of agriculture on inland sites seems to have had a much more profound effect than it did on the coastal sites. This is particularly seen in the large increase of storage structures (Table 8.2). It is possible, contrary to Hinton (1982), that it was the agriculturalists who used their anterior teeth for specialist functions for preparing food and non-dietary activities.

### ***Non-agricultural comparisons***

There were slight differences between the non-agricultural assemblages. The Levantine assemblages and the Santa Barbara group had the highest median values for occlusal wear for all teeth (relative to M1 occlusal wear) and the Levantine assemblages had the highest median approximal lengths and occlusal wear plane angles (relative to M1 occlusal wear). This suggested that the non-agricultural collection should be divided by regions. The North American and Levant groups (chapter 7, section 7.3.B) showed little difference in the pattern of occlusal wear, but the Levantine group had larger approximal facets (relative to M1 occlusal wear) and occlusal wear plane angles (relative to M1 occlusal wear) than the North American group. The inland group had more anterior teeth occlusal attrition (relative to M1 occlusal wear) than the coastal group, and P1, P2, M2 and M3 occlusal attrition (relative to M1 occlusal wear) was similar between the groups. Approximal facet lengths were similar in both the coastal and inland groups but the occlusal wear plane was more strongly angled (relative to M1 occlusal wear) in the coastal group than the inland. Neither the Levant nor the North American non-

agriculturalists strongly follows the expected wear pattern, outlined in the hypothesis above, but the North American group departs from it even more greatly than the Levant group. The inland group had a strong occlusal wear gradient in the anterior teeth and no strong gradient of approximal wear. These findings show differences between coastal and inland groups for the anterior teeth.

### ***Agricultural comparisons***

As with the non-agriculturalists, there were slight differences between the agricultural groups. Hawikuh and Shannon had more anterior occlusal attrition (relative to M1 occlusal wear) and approximal wear (relative to M1 occlusal wear) for all the teeth than the other groups. Florida and Abu Hureyra had more posterior occlusal wear (relative to M1 occlusal wear) than Hawikuh and Shannon, and Abu Hureyra had the steepest occlusal wear plane angles (relative to M1 occlusal wear) of the agriculturalists. Hawikuh and Shannon stand out amongst the North American sites, while Abu Hureyra was consistently different. With this in mind, a separate comparison was made between Abu Hureyra (the only Levant agriculturalist) and all the North American agriculturalists, there was little difference in the pattern of occlusal wear and approximal wear but Abu Hureyra had larger occlusal surface angles relative to M1 occlusal wear than the North American group. This was a similar finding to the comparison of the North American and Levant non-agriculturalists above. The coastal and inland groups were also compared. The coastal and inland comparison, on the other hand, was somewhat different to that of the non-agriculturalists. The inland agriculturalists had a strong occlusal attrition gradient for the anterior teeth (as seen in the inland/coastal non-agriculturalists) but the coastal agriculturalists had more P1, P2, M2 and M3 occlusal attrition (relative to M1 occlusal wear) than the inland group (unlike the coastal/inland non-agriculturalists). The approximal wear was similar between the inland and coastal agriculturalists. The coastal agriculturalists had more strongly angled M1 occlusal surfaces relative to M1 occlusal wear than the inland group (similar to the non-agriculturalists). To some extent the differences between the coastal and inland non-agriculturalists are also seen in the inland and coastal agriculturalists, there however were some differences. This may well be explained by exploitation of coastal resources in agricultural communities. In spite of the strong contrast in the environmental and cultural context of the sites there was not nearly as strong a difference in pattern of tooth wear as was found for the non-agriculturalists. Amongst the North American sites it is unclear why Hawikuh and Shannon were so consistently grouped together in tooth wear pattern.



### **Comparisons between the males, females and unknown sex groups**

Generally there was little difference between the males and females, but the unknown sex group showed much greater variability than either of the known sex groups. It is possible that the unknown sex group included more young individuals who had not yet developed characteristics for either sex and the teeth were also little worn. The other possibility is that older individuals with more wear might have had porotic bone and the skeleton might therefore been more damaged which removed the features most useful for sexing. Only in the non-agriculturalists was there a difference between the known sexes. The males had larger median values for anterior, premolar, and molar occlusal attrition and molar occlusal angles (relative to M1 occlusal wear) than the females. The approximal wear however, was similar between the known sexes.

### **Possible explanations**

Summary of findings from results in chapter 7

	Anterior occlusal wear	Approximal facet length	Occlusal wear plane angle
AGR / TRANS	+	+	+
NON-AGR*	-	-	-
INLAND	+	=	-
COASTAL	-	=	+
(AGR/TRANS /NON-AGR)			
LEVANT	=	+	+
N. AMERICAN (NON-AGS only)	=	-	-
LEVANT	=	=	+
N. AMERICAN (AGS only)	=	=	-

Table 8.1: Summary of the findings from the results in chapter 7. (AGR=agriculturalists, TRANS=transitionals and NON-AGR= non-agriculturalists. + greater wear, - less wear and = similar wear relative to M1 occlusal wear). \*The findings of the agriculturalists, transitionals and non-agriculturalists were more marked in the inland comparisons than the full collection and coastal comparisons.

Hinton (1982) stated that non-agriculturalists had more approximal wear relative to occlusal wear which was due to the magnitude and frequency of application of a mesial force vector (see chapter 2 for more details) and repetitive chewing to eat a diet of seeds, wild plant foods, and small animals for which food preparation (grinding/cooking) was minimal or non-existent. So the observed differences in approximal wear were seen less as the result of what was being eaten, but in which the way the food was prepared for consumption.

The findings from the present study however, did not show the non-agriculturalists to have more approximal wear relative to occlusal wear, but less (Table 8.1). Hinton's interpretation would imply greater mesial forces applied by agriculturalists than non-agriculturalists. It is possible that the groups studied processed their food in a different manner as well as differences in diet. Similarly, it is possible that agriculturalists

used their teeth more heavily for a different range of non-dietary tasks. Either of these would imply that there is considerable variation between groups of agriculturalist and non-agriculturalists therefore Hinton's interpretation is not universal. The collections for this study were from different areas in North America than the collections that Hinton used, as well as assemblages from the Levant. Second, Hinton only used the arithmetic mean to summarise scores. The plots in the present study show the range of variation to be large and this has to be taken into account when making comparisons. Lastly there is the method of recording occlusal wear. Hinton compared a direct measurement of approximal facet length with an ordinal system of occlusal wear scores. In the present study, occlusal attrition was measured by a proportional area method (Methods chapter 6, section 6.2). This shows a good relationship and a much greater range of intermediate stages. It is therefore possible that this affected the results. The nature of occlusal facet measurement is discussed further below.

The results of occlusal wear plane angles were similar to the findings of Smith (1984). There were still some differences between her study and the present one, but these variations did not affect the overall findings. According to Smith (1984), the worn occlusal surface, agriculturalists angle changed more rapidly to the degree of occlusal wear than it did in non-agriculturalists. She suggests that heavy use of the teeth in preparing tough foods would involve wider lateral movements of the jaw which would tend to produce more horizontally aligned attrition facets. These explanations could be applied to the present study but it is difficult to match these to the finding of approximal wear above.

Occlusal attrition gradients, approximal wear facets lengths and occlusal wear plane angles were more marked (relative to M1 occlusal wear) in the inland groups than the full collection and coastal groups (Table 8.1). This may imply that the inland assemblages underwent a more sudden adoption to agriculture, where not only the toolkits changed markedly, but also diet, methods of food processing and daily tasks. The excavations at these sites indicate an alteration of diet with, including heavy use of maize squash and beans but still continued gathering of seasonal nuts and fruits. The fundamental changes accompanying this is the concentration of storage and refuse pits and pottery (Table 8.2). There is therefore at least some evidence to suggest that food processing activities might have changed. The agricultural coastal sites, by contrast, continued to show evidence of fishing and gathering of marine and coastal resources. In addition to the use of maize and other cultivated crops. It is less easy to show clear

of measuring occlusal wear and seems to show more sharply defined difference between behavioural groups than the more usual approximal facet length. The results are effectively the same as described above, but in future study might benefit from the use of this alternative technique.

## 8.4 Summary

To sum up, each dental wear feature was tested individually from the previous results. It was found that:

- high occlusal wear rate in non-agriculturalists relative to independent age indicators
- gradients of occlusal and approximal wear did exist in the dentition, but were strongly related to the eruption sequence and size of the teeth –the agriculturalists and transitionals showed a stronger gradient than the non-agriculturalists
- the agriculturalists and transitionals showed a higher rate of change of occlusal wear plane angles per stage of M1 molar occlusal wear than the non-agriculturalists which supports Smith's (1984) original hypothesis
- there was some variation between North American and Levant groups, particularly in the non-agriculturalists occlusal wear facet angles
- both the anterior teeth occlusal wear and approximal wear (relative to M1 occlusal wear) were heavier in the agriculturalists than the non-agriculturalists, which was the opposite of the findings of Hinton (1981) –perhaps because the assemblages were from different environments and different cultural groups
- differences between agriculturalists and non-agriculturalists were greatest in the inland groups than in the coastal groups possibly because the coastal group had a more gradual adoption of agriculture, with more continued use of gathered and fished resources
- the largest intra-behavioural group variations were between the inland and coastal assemblages, both for non-agriculturalists and agriculturalists
- an improved alternative method for measuring approximal attrition is proposed from the experience gained during the project

Differences of collections used, their associated toolkits, nature of foods, non-dietary tasks and methods of study most likely influence the occlusal attrition, approximal wear and occlusal wear plane angles.

## Chapter 9 — Conclusion

One of the successes of this project was the establishment of new methods of studying tooth wear. The occlusal surfaces were recorded using a standard digital camera and the proportion of dentine exposed in the occlusal wear facet measured using inexpensive image analysis software. This was really no more than an update of Richard and Brown's approach which used photographic prints and a planimeter in a similar way, but it was particularly rapid and trouble free using current technology. At the end of the project it was also found that approximal facet attrition size could be expressed as the outline of the occlusal surface. This was entirely new, and made a much better unit of comparison for occlusal attrition as defined above. It would be well worth using these methods for future studies of tooth wear.

The results agree with the findings of Smith where the non-agriculturalists showed a slower change in occlusal facet angle relative to the extent of occlusal wear than the agriculturalists and transitionals. The transitionals showed results much like the agriculturalists, which has not been demonstrated before. In addition there was a consistent difference in wear angles between inland and coastal groups. Once again this had not been demonstrated in Smith's study. Clearly the transition between non-agriculturalists and agriculturalists is rather more complicated than has been previously suggested.

On the other hand, completely opposite results to Hinton's study were obtained from the material studied here. Once more this shows that this situation is more complex. Non-agricultural groups from different environments in North America and the Levant must have differed greatly in diet and the activities for which they used their teeth. The same must be true for the agriculturalists and transitionals. In the light of the results, it is perhaps better not to attempt to characterize non-agriculturalist tooth wear in any general way. Much more work is needed on variation in patterns of tooth wear, and this should be the focus of any future project.



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